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The Magazine of Space Exploration

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RAIN FROM THE UNIVERSE

CHARTING THE SEAS OF THE SOLAR SYSTEM

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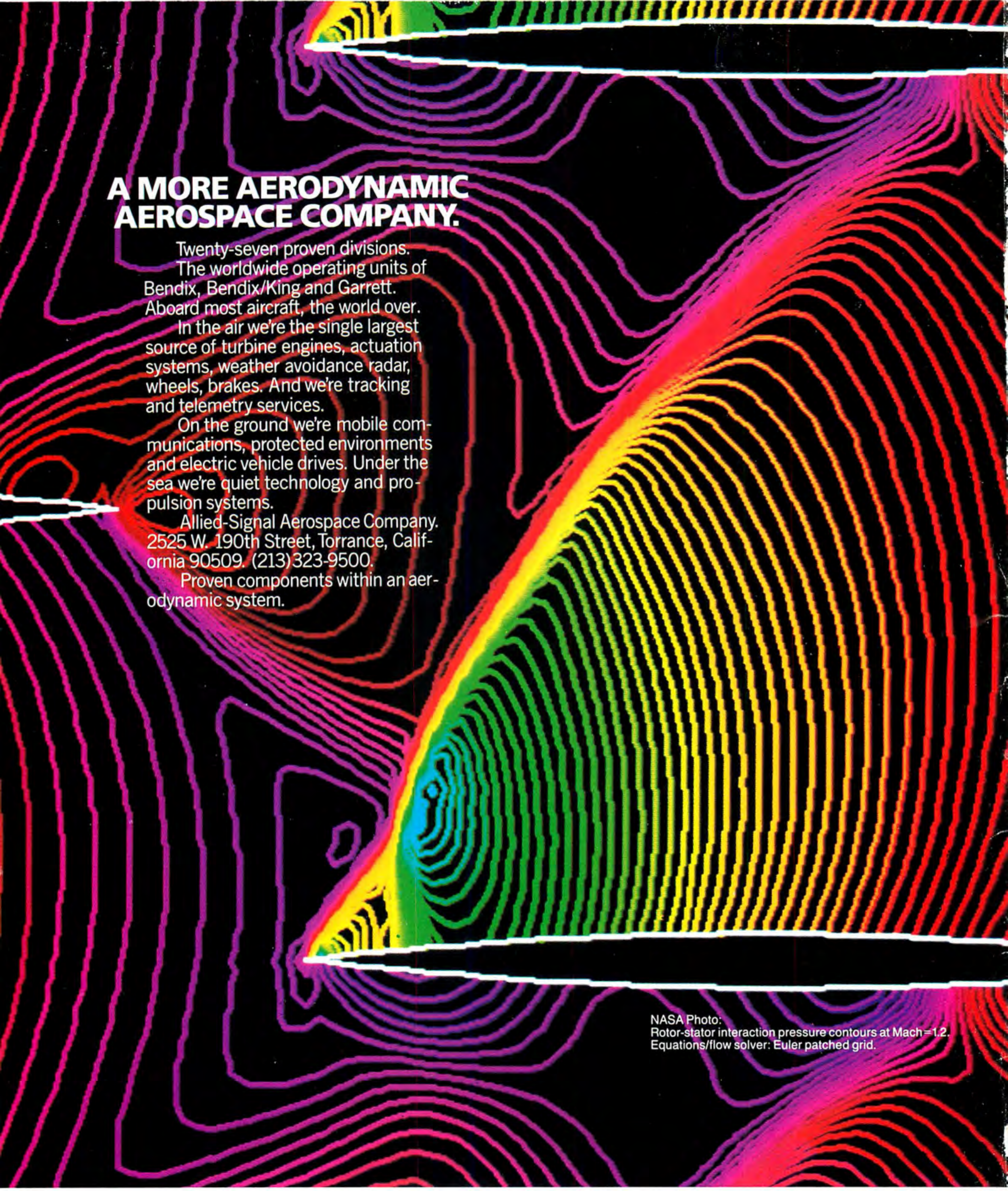

NASA Photo:
Rotor-stator interaction pressure contours at Mach=1.2.
Equations/flow solver: Euler patched grid.

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"Better than an E-ticket at Disneyland" is how Sally Ride described the shuttle astronaut's swift ride into orbit. See the article on page 18.

July/August 1988
Volume 1, Number 3

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FROM THE PUBLISHER

It's gotta be good
and it's gotta be a lot
and I've gotta have it now."
—Cracker Jacks jingle.

I'm impatient. I grew up on commercials that promised me I could have anything I wanted right away, if not sooner. And when I saw astronauts bounding across the lunar plain, I decided I wanted a piece of the action.

It hasn't happened. I haven't gotten my crack at the great Tilt-A-Whirl in the sky, unlike the good congressman in our cover story. And I'm not happy.

At least I was unhappy enough to start my own magazine. Now in our third issue, I'm finding even more people who think the way I do.

We just can't find a good reason that more earthlings aren't traveling around the solar system. Or navigating some of the seas we're discovering right in our Solar System (and you'll discover on page 27) .

In this month's "Observatory" column, Wally Schirra tells what he thinks went wrong with the space program. Others will blame it on the government or the press. Or even the people.

You'll probably find a good range of opinion in this column. It's not meant to be exclusive. Only provocative. Like Final Frontier as a whole, the "Observatory" is a cosmic suggestion box.

NASA is expecting nearly 7,000 media people at the cape, covering the imminent launch of Discovery. 7,000 media people! Wish I had the coffee concession.

Only a couple hundred witnessed the Challenger. I would hate to think that the other 6,800 are chasing fire trucks. I have to think they're part of the groundswell we've been seeing in the circulation office... okay, "cube."

Whatever the reason for the excess of journalists, they'll be serving a very important function—focusing our attention once again on the sky.

Maybe we'll at last end the analysis and start the countdown. It won't be any too soon. Take it from me, a certified member of the Cracker Jack generation.

Ever upward,

William Rooney

William Rooney
Publisher

FINAL FRONTIER
THE MAGAZINE OF SPACE EXPLORATION

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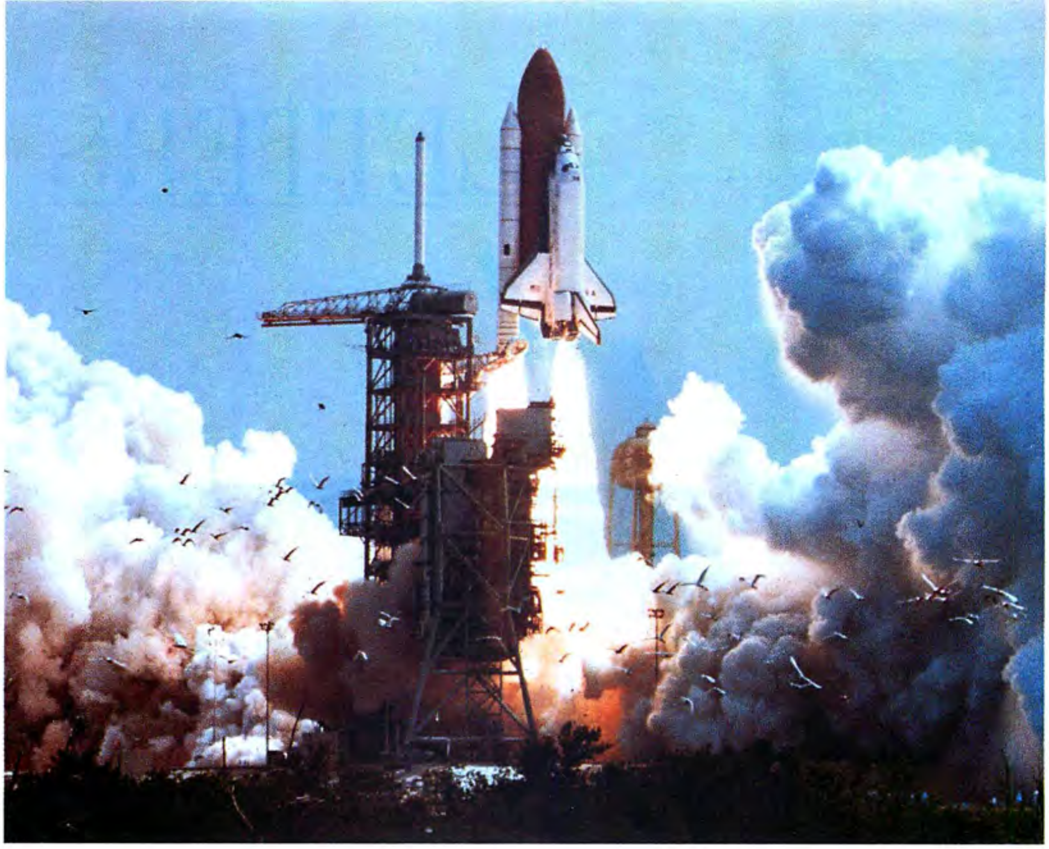

AMERICA'S PRIDE: THE JOURNEY CONTINUES...

It's the moment we've all been waiting for. And working for. When the Space Shuttle *Discovery* roars off the launch pad later this summer, America will be resuming one of the most unique endeavors of its kind in the world. With *Discovery* the Nation will be continuing its program of regular manned access to space, and forging ahead with the crucial research and pioneering work that the mission entails. And soon, that mission will include a *permanent* manned presence in space with America's space station.

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LETTERS

So Quit Your Worrying

It is strange to read about the worries of some people, like Soviet theorist L.M. Shkadov (April 1988), who would like to rescue Earth from the explosion of the dying Sun, an event which is at least five billion years in the future.

Even in a million years, humanity will spread far beyond the Solar System. The Earth will be just one of the millions of inhabited worlds. Some of them, perhaps, would have faced the problem of a dying star even before the Earth. The solution is self-evident. The inhabitants of such worlds will simply move to the planets of younger stars.

And in five billion years, when the Sun's turn comes, what then? Will the loss of one planet, or one Solar System, mean anything to the humanity spread through the galaxy? Would those people remember the Earth as their birthplace? Will they resemble present day men and women, or even need a planet for their existence?

Even if the answer to all these questions is yes, I am sure in five billion years they would think up something which none of us, including Mr. Shkadov, can even comprehend.

Arkady A. Alexeev
Berkeley, California

NASA is the Problem

I think Congressman George Brown's proposal ("The Observatory," June 1988) to add space settlements to NASA's mission is exactly the wrong way to go. We do not need space settlements to become entangled in the same bureaucratic and budgetary quagmire the space station has become bogged down in. Nor do we need a space settlement program to be run like the shuttle, which attempted to be everything to everyone and ended up too expensive for anyone. Nor do we need the government trying to protect NASA's monopoly, as you report on page 10 of the same issue, with regard to microgravity experiments on the Soviet Mir station. We will not get space settlements until we recognize that NASA is the problem, not the solution.

Joseph P. Martino
Sidney, Ohio

It's Official: It's Optional

Allow me to correct an erroneous characterization of the Jet Propulsion Laboratory put forth in the April issue's "Letters" column by Lindsey V. Maness, Jr.

Contrary to Mr. Maness' assertion, JPL does not receive "the lion's share" of its funding from the Department of Defense. More than 70 percent of the Laboratory's funding comes from the National Aeronautics and Space Administration.

JPL is and has always been a division of the California Institute of Technology. From 1939 to 1958, JPL was operated for the U.S. Army. It was transferred to NASA on December 3, 1958, two months after that civilian agency was created by Congress. Since then, JPL has been operated by Caltech employees under a contract to NASA, which owns the Laboratory.

JPL may be described as NASA's Jet Propulsion Laboratory or Caltech's Jet Propulsion Laboratory.

Robert J. MacMillin
Manager
JPL Public Information Office

FINAL FRONTIER welcomes your letters. Send them c/o Letters to the Editor, FINAL FRONTIER, P.O. Box 11519, Washington, D.C. 20008. Please type your correspondence and limit the length to 150 words.

THE OBSERVATORY

Send Only the Best

One of the Original Seven says we should keep space crews exclusive.

▼ ▼ ▼

by Walter M. Schirra

W*ally Schirra was unique among the early astronauts in that he was the only man to pilot all three of NASA's spacecraft of the 1960s — Mercury, Gemini and Apollo. Twenty years ago, Schirra was deeply involved in the recovery effort following the Apollo 1 launch pad fire in 1967, and he played a key part in overseeing the redesign of the craft that later carried astronauts to the Moon.*

Last spring, during another period of recovery for NASA, the former astronaut was interviewed at the International Aerospace Hall of Fame in San Diego. The following is adapted from that interview:


NASA

Schirra (center) with his Apollo 7 crewmates, and (below) near the end of their 1967 flight.

Without a commitment, we are going to give away the beachhead we established in space. If we are going to be a world leader in technology and commerce, we must have a presence in space, and if we want to practice being in space, we should do it in Earth's orbit, where we can return to Earth in 14 or 15 minutes.

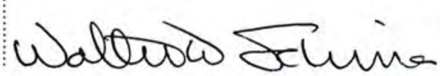
When we began in Mercury, all seven of us were graduates of test pilot school. The second group of nine astronauts were also test pilots. But by the time the third group was selected, test pilot experience was no longer a requirement, and I have come to believe that this was a mistake. We lost that inquisitive, demanding engineering mind developed by test pilot school. There was not the capability to follow engineering and design logic without querying every point or communicating with the engineering and design community. Earlier we had transitioned from the "scarf and goggles" test pilot to the "engineering test pilot," and this was a step backward.

To send someone out into space, we must be assured of receiving more in return than the cost of sending that particular individual. For that reason I was distressed when NASA began sending a Senator and a school teacher up. That seemed unrealistic to me, in that those flights cost some three hundred million dollars each . . .

There were tremendous responsibilities in Apollo as compared to Mercury. In Mercury the seven of us literally reported to each other, backed each other up and worked together as a team. In Gemini, things thinned out a bit, with a prime crew of two and a backup crew of two. Tasks became more complicated.

In Apollo we had a prime crew, backup crew and support crew, and I was essentially in command of nine astronauts. We also spent a tremendous amount of time with the command and service module as it was being built. Later crews spent more time in simulators practicing their tasks, which could be a compliment to my crew because they did not have to worry about the spacecraft anymore.

This attitude of not worrying about the spacecraft is my point. With the shuttle, they lost track and they got burned, literally, in Challenger. □

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GLOBAL CURRENTS

A Pan-American Space Agency

Helping Latin America step into the space age.

▼ ▼ ▼

By Devera Pine

Should the United States, Canada and the countries of Latin America join together to form a west-of-the-Atlantic version of the European Space Agency? Astronaut Franklin Chang-Diaz thinks so.

Chang-Diaz, who was born in Costa Rica, joined NASA in 1980 and flew his first shuttle mission in 1986. Now he is one of those heading the drive to form a group called PASO—the Pan American Space Organization. ("Paso," Chang-Diaz points out, is also Spanish for "step.") As Chang-Diaz and others see it, PASO would help Latin America take its first steps into the space age.

The United States has worked with Latin America before on space ventures, but only on a country-by-country basis, says the astronaut. Under PASO, though, all the countries would work together on programs. Like the European Space Agency (ESA), PASO would become a kind of Common Market for space, with all member nations contributing and benefiting. "By coordinating the efforts—however small—of individual countries, you have a pretty good effort."

Example: Argentina is currently putting together a satellite to study solar flares. "We want to use that satellite as a starting point for the creation of this space organization," says Chang-Diaz. The satellite would be launched in the United States on a small Scout rocket, into a polar orbit with an altitude of 300 miles.

The real international cooperation would occur in the tracking: Argentina has just one tracking station, which would be able to receive only about 10 minutes worth of signals from the satellite each day. However, there are tracking stations in Brazil, Chile, Ecuador, the United States and Canada. Under PASO, all of these stations would track the satellite. In exchange, Argentina would share the data it receives.

PASO's organizers are wary about the possibility that the United States would dominate—instead of simply participate in—the organization. "We want to have one country take the lead, so that the whole thing does not become a U.S.-driven concept, but comes out of Latin America," says Chang-Diaz. At the moment, the country taking the lead is Costa Rica.

Obviously, Latin American countries would benefit from this sort of organization because the United States could give a technological boost to their still-young space programs. The United States would also benefit, though, because it would gain an equatorial launch site (the closer a launch site is to the equator, the less fuel it takes to get a satellite into geosynchronous orbit).

NASA

NASA

Astronaut Franklin Chang-Diaz (top, and with mission 61-C crewmates, below) is among those pushing for PASO, a space consortium of American nations.

"It would open a tremendous capability for the United States and Canada to launch rockets from the equator," says Chang-Diaz. "There would be a tremendous payload capability." Ironically, the European Space Agency already has an equatorial launch site in south America, located in Kourou, French Guiana.

Another, less clear-cut advantage: "Sooner or later Latin America will develop, and if the United States is not there with a good solid relationship, those countries are going to look toward Europe for their development," says Chang-Diaz. "The United States will find itself alone."

Brazil, which already has active programs in satellite development and space research, may be a case in point. The country sent up its first domestic communications satellite, Brazilsat 1, in February 1985. Significantly, it was the European Ariane rocket that launched the $50 million spacecraft, not the U.S. shuttle.

In the United States, it will be up to Congress to decide whether or not to support PASO. So far, says Chang-Diaz, the signs are positive; Congress seems to support the idea.

The real problem will be getting the countries of Latin America to work together. Chang-Diaz, in fact, calls this a "major barrier." In general, he says, Latin America has not been able to sustain multinational cooperation agreements—which is why it's so important that the driving force for the program come from Latin America, he says.

Chang-Diaz is now helping to organize an international advisory board for PASO. By April of next year, he hopes to have an international congress, with a few delegates from each of the interested nations. The congress will assess whether or not the countries want to form PASO and will propose a cooperative exercise with Argentina's solar satellite.

If all goes well, when the satellite is launched in 1992, stations all across North and South America will track it. And after that, says Chang-Diaz, "we'll see what happens." □

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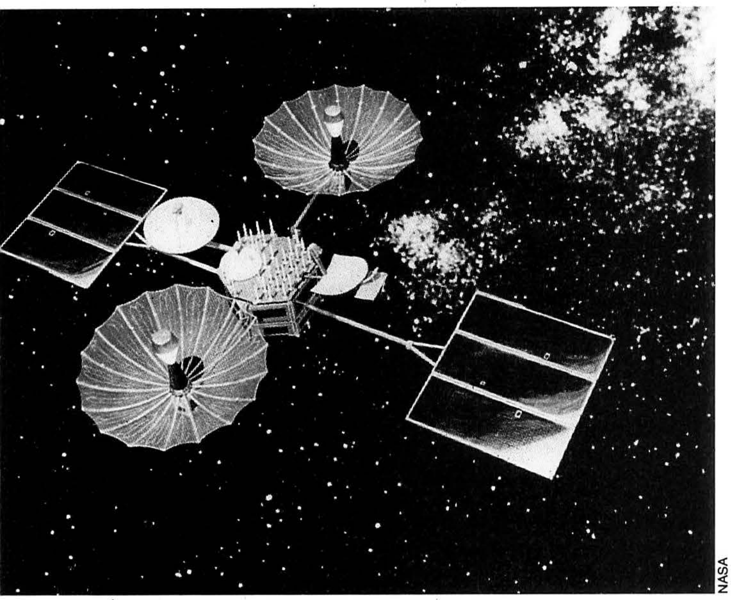


TDRS will help astronauts stay in touch.

NASA PHONES HOME

Of all the dozens of spacecraft stranded on the ground since January 1986, guess which one will be the first carried into space aboard the space shuttle when it resumes launches? Easy. A communications satellite so the crew can phone home.

The only primary payload on the long-awaited 26th shuttle flight will be a Tracking and Data Relay Satellite, or TDRS (pronounced tee-driss). It will join an earlier TDRS that has been coping single-handedly since 1983. From a geostationary orbit 22,300 miles above the planet, each satellite will cover half the globe while appearing to remain fixed in one spot in the sky: together they can reach out and touch virtually every NASA spacecraft in low Earth orbit.

For scientific research satellites in low orbit (between 100 and 300 miles above the ground), communication is vitally important. Spacecraft like the Landsat Earth observation satellite and the Hubble Space Telescope scheduled for launch next year must beam down huge quantities of data almost around the clock. Calling Earth is even more important for manned vehicles. Adjusting in-flight experiments, handling repairs and emergencies, building and then occupying the space station—all will require nearly continuous counsel from below.

Before TDRS, a ring of 15 ground stations around the world intercepted calls as the shuttle shot overhead at four miles a second. Even so, Mission Control was only able to talk to astronaut crews for about 15% of each orbital pass. With the TDRS relay satellite above instead of underneath it, the shuttle is within earshot for most of its orbit.

"The ninth shuttle mission, which was the first to use TDRS, sent more information back to Earth than all 39 previous manned missions put together," says Montye Male, public relations manager for the satellite's builder, TRW Inc.

TDRS did it by relaying voice, television, analog and digital signals at an exceptionally rapid clip: 300 megabits of data per second. In more common parlance, "That's the equivalent of 100 volumes of the encyclopedia a second," says Male. Each TDRS can juggle the calls of 40 different NASA spacecraft at a time.

It takes a big bird to do such a big job. The TDRS is the largest (57 feet) and heaviest (5000 pounds) communications satellite ever launched. Only the shuttle can lift it, and it needs an additional boost from an Inertial Upper Stage rocket to climb from low orbit to its high geostationary perch.

Two working satellites and a third in-orbit spare eventually will complete the system (the original companion for the currently orbiting TDRS was lost in the Challenger accident). The satellites each have a lifespan of ten years, and need only a single ground station at White Sands, New Mexico. With the TDRS system in place, NASA can expect to get a lot more conversation for its nickel.

—Joanne Heckman

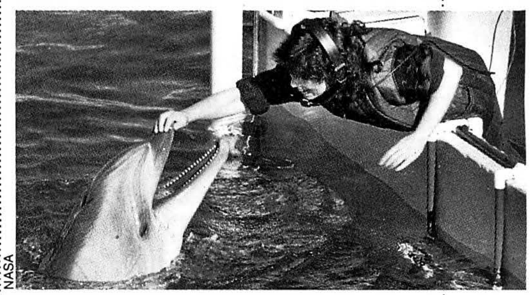
PARLEZ-VOUS DOLPHIN?

Would dolphins help us learn how to talk to extraterrestrials? Just possibly, according to communications specialist Diana Reiss of San Francisco State University.

When and if we ever find intelligent life elsewhere in the universe, says Tom McDonough of the Planetary Society, we can expect to find radically different assumptions and communication systems. That's why, as coordinator of the Planetary Society's SETI (search for extraterrestrial intelligence) program, he and other SETI researchers are watching Reiss's work with keen interest.

Called "Project Circe," Reiss's study of a group of dolphins at the Marine World Foundation in Vallejo, California, is now seven years old. "When it comes to studying animal communication on our own planet," says Reiss, "we're relatively blind and deaf." The toughest task, she explains, is to find solid ground between the anthropomorphic view (endowing other animals with human traits) and an anthropocentric one (assuming that no other species could possibly possess complex communication systems).

Why focus on dolphins? They are large-brained mammals, with a brain-to-body ratio comparable to humans. Yet they live in a far different environment, and they've developed a complex, truly alien communication system involving "constellations" of whistles, clicks, audible pulses, pectoral fin slaps and dozens of other movements. The challenge is to crack the code.



Learning Flipper-speak may teach us to chat with aliens.

That's where a self-critical approach, and Reiss's varied background in cyber-

netics, animal behavior, bio-acoustics and comparative physiology and psychology, come in. With the help of Planetary Society funding and, Reiss hopes, a NASA grant, she'll use a computer to scan for significant patterns, in much the same way SETI researchers would hope to crack the code of an extraterrestrial radio signal. Practice with these water-borne mammals could pay off when (and if) we're eye-to-tentacle with someone who has no common roots with us at all.

—Ray Spangenburg and Diane Moser

A BRIGHTER CHIRON

The far-off asteroid Chiron, which has puzzled scientists for more than a decade, just got a bit easier to see. Astronomers recently checked up on the mysterious object, whose orbit lies between Saturn and Uranus, and found it nearly twice as bright as normal.

"It caught us off guard," says the University of Hawaii's David Tholen. Tholen had been observing Chiron for years, with no change in its generally faint appearance. "It was almost getting boring, but finally we hit pay dirt."

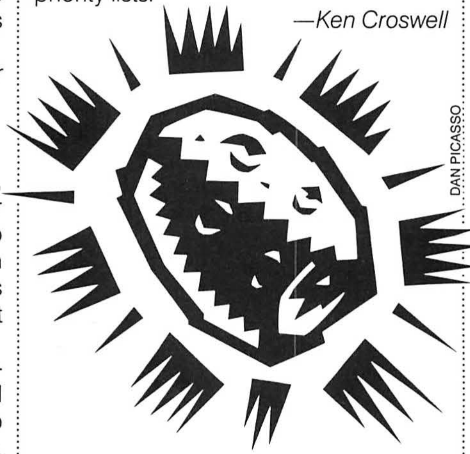
In late February Tholen and colleagues discovered Chiron to be 90 percent brighter than usual, and in March he made observations that confirmed the brightening. Newly analyzed data from late 1987 also show a brighter Chiron.

Scientists aren't sure whether the object, whose size is estimated at anywhere between 60 and 250 miles in diameter, is an icy comet, or a rocky asteroid, or something in between. Most asteroids are found nearer to the Sun, while comets reside in the outer Solar System.

"Right now a cometary explanation [for the brightening] is the only one that makes sense," says Tholen. As comets near the Sun and warm up, they often brighten as their ices melt. Chiron normally lies between Saturn and Uranus, but cuts inside Saturn's orbit at its nearest approach to the Sun. The object's 51-year orbit will bring it around the Sun again in 1996, and Tholen thinks its ices may be melting as it gets closer. However, he notes that a similar brightening also occurred in 1978, when Chiron was much farther from the Sun.

Brighter though it may be, Chiron is still very faint—25 times fainter than Pluto. Nonetheless, scientists will certainly want to keep an eye on the mystery object, which hasn't been in the news much since astronomer Charles Kowal discovered it back in 1977. Says Tholen: "It's certainly going to move the object up on people's priority lists."

—Ken Croswell



DAN PICASSO

CONFLICT RESOLUTION

Try as they might, space medical experts have yet to come up with a sure-fire cure for the space sickness that afflicts a large percentage of the astronauts and cosmonauts who venture into orbit. By teaching the brain to ignore or reinterpret certain sensory cues, scientists at NASA's Johnson Space Center now hope to develop a drug-free remedy for the malady called Space Adaptation Syndrome (SAS).

From experiments on previous shuttle flights, scientists have determined that a sensory conflict between signals from the balance organs of the inner ear and visual cues are what lead to space sickness. In weightlessness, what looks like "up" may not feel like "up," since the inner ear, which in normal gravity senses motion, no longer provides reliable sensory information.

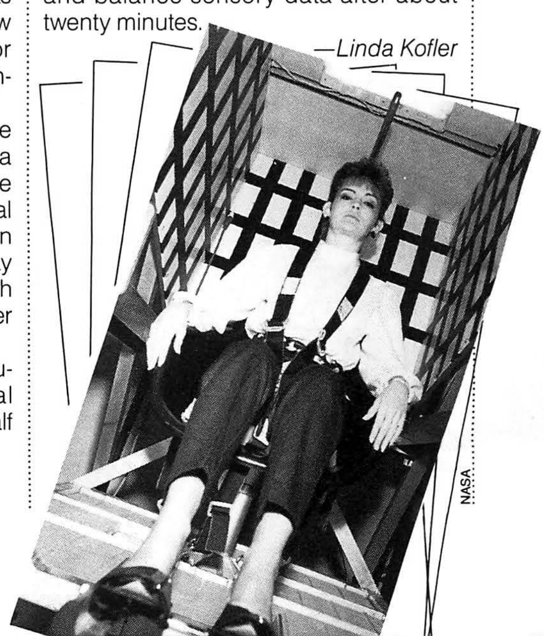
According to Frank Kutyna, Chief Neuroscientist of the Space Biomedical Research Institute at Johnson, at least half of all astronauts suffer the nausea and disorientation that results from this sensory conflict within the first three days of spaceflight. Donald Parker, who has sponsored studies of space sickness on the Shuttle, hypothesized that astronauts could learn to prepare themselves for the sensory conflict experienced in space by spending time in a special trainer on Earth.

The Preflight Adaptation Trainer (PAT), therefore, has four modes for simulating the confusion that occurs in weightlessness. All the modes keep the inner ear from sensing changes in the direction of gravity's pull, either by keeping the subject restrained while the room or visual scene moves, by having the subject lie in a prone position perpendicular to gravity, or by moving the subject and the visual scene in unison.

Once the subjects are trained to interpret visual changes without a corresponding gravitational cue from the inner ear, they must also learn to cope with the sensory conflict that occurs. None of the modes are designed to make the test subjects sick, but rather to adapt gradually to sensory rearrangements.

How much training will be required to overcome space sickness—and how long the effects from pre-flight training will last—are two questions that cannot be answered without further research. But according to Kutyna, subjects show measurable changes in their handling of visual and balance sensory data after about twenty minutes.

—Linda Kofler

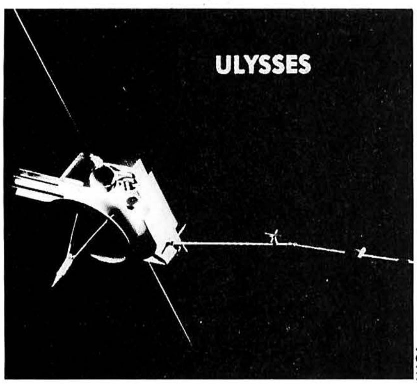


NASA

Welcome to the funhouse: the Pre-Adaptation Trainer.

WHERE NO PROBE HAS GONE BEFORE

The mythic hero Ulysses took the long way home from the Trojan wars, sampling the riches of life along his way. In 1990, a spacecraft named after him will take the long way around the Sun to plumb the mysteries of the powerhouse that fuels life on Earth.



NASA

The European Space Agency's Ulysses probe is scheduled to be launched from the shuttle on a five-year mission to give scientists their first view of the polar regions of the Sun. To get there, however, it will need to travel to Jupiter and swing over the giant planet for a gravitational boost out of the orbital plane of the planets.

Three years after launch, Ulysses will fly over the south pole of the sun at a distance of 186 million miles, twice the distance at which Earth orbits the Sun. Nine months later, it will pass over the solar north pole.

One of Ulysses' tasks will be to study the Sun's magnetic field, which creates Sunspots and solar flares. The combination of the Sun's rotation and the steady flow of charged particles, called the solar wind, emanating from its surface, results in a twisted mess of magnetic field lines in the solar equatorial regions. Solar physicists presume that at the poles, the field lines will be fairly straight and easier to study.

Ulysses will carry nine instruments and 11 experiments, involving more than 100 investigators from 12 countries. Beside the magnetic fields, the experiments are intended to study the Sun's corona—visible to the naked eye only during eclipses—the solar wind, solar and nonsolar cosmic rays in the Sun's polar regions, radio energy bursts from the Sun, and interstellar gas and dust in the vicinity of the poles.

NASA caused bad feelings among European Space Agency officials in 1981 by cancelling its half of what was then a two-spacecraft mission as a cost-cutting measure. The United States is still providing a shuttle launch and power source for Ulysses, and some of the investigators who will fly experiments aboard the spacecraft are American.

NASA's decision after the Challenger accident to bump Ulysses from its number-one position in line for an interplanetary launch slot, in favor of the U.S. Galileo mission to Jupiter, caused further ill will. ESA's top space science official, Robert Bonnet, confirms that the launch date for Ulysses is a highly sensitive subject. If politics caused NASA to bump Ulysses once, politics could interfere again.

—Linda Billings

VINTAGE TOMATOES

Remember those millions of tomato seeds that NASA sent up into orbit four years ago to *see how they'd* fare? Well, they're still up there. And they may never be seen again, unless the agency does something soon.

The problem that once faced the Skylab space station now confronts NASA'S Long Duration Exposure Facility, or LDEF, which is losing orbital altitude faster than expected. Back in 1979, NASA couldn't keep the 100-ton Skylab from falling onto the Australian outback. But by rearranging the shuttle schedule, the space agency hopes to retrieve LDEF before it crashes to Earth.

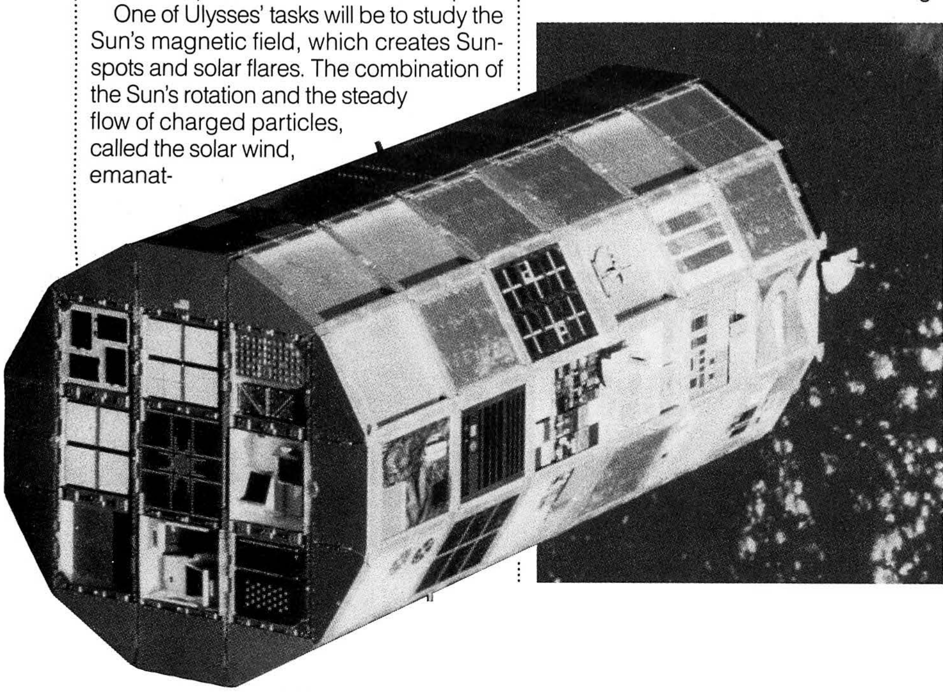
A reusable satellite, LDEF carries experiments that require long-term exposure to the space environment and its extremes of temperature, microgravity and solar radiation. With 85 experiment compartments, LDEF is a cylindrical satellite 40 feet long and 14 feet wide, which fits snugly into the shuttle's payload bay.

When LDEF was carried into space by Challenger in April 1984, it had 57 experiments onboard, ranging from studies of how different materials stand up in the space environment, to meteoroid impact investigations, to cosmic ray analysis.

NASA intended to bring LDEF back to Earth ten months later, but because of shuttle schedule changes, and then the Challenger accident, the satellite is still stranded in orbit.

At first this didn't worry NASA officials. LDEF had been placed in a 290-mile high orbit that would be stable until 1995. Earlier this year, however, the North American Air Defense Command determined that the 21,400-pound satellite is losing altitude at a rate that will bring it tumbling back to Earth by 1990. Because LDEF is a passive satellite (it has no thrusters for changing its position in orbit), there's no way to control its reentry. And while most of the vehicle would burn up during reentry, large pieces would be sure to reach the ground.

The retrieval mission, tentatively scheduled for the 32nd shuttle flight in June 1989, will bring LDEF and its cargo back to Earth. Some of the onboard experiments will not have survived the extra four and a half years in orbit, but one project expected to fare well is the tomato seed experiment. The George Park Seed Com-



NASA

LDEF, still orbiting after all these years.

pany placed 12.5 million seeds aboard LDEF to learn how space affects seeds and to what extent mutations will occur after exposure to cosmic rays.

According to Jim Alston, Director of Research for the Park Seed Company, the extra on-orbit time probably won't hurt the seeds, although the added time will increase the number of mutations. And no, he doesn't think that any of the mutations will be dangerous. The only threat to the seeds, Alston said, is heat. Temperatures onboard LDEF were higher than expected, though still within tolerable limits.

Many of the seeds will be examined and studied by scientists at the Park Seed company. Many more will be packaged and distributed to schools around the country. If the LDEF is returned safely to Earth next summer, space-tomatoes could be growing for high-school science projects during the next school year.

—Robert G. Nichols

AND NOW, OFF-EARTH BANKING

Mining the Moon for extraterrestrial ores is an oft-mentioned strategy for making future lunar colonies economically self-sufficient. But James Sanchez, of the Aristarchus Group in Tucson, Arizona, says he has a better idea.

In a paper delivered at a recent NASA conference on lunar base development, Sanchez proposed an alternative product, which he claims will lead to a booming economy on the Moon: information.

A lunar information industry would be modeled after contemporary offshore banking, insurance, data processing and teleservices industries on Earth. What makes these ventures profitable, Sanchez says, are tax and regulatory advantages protected by law. He cites the "captive insurance firms" in the Caribbean and Bermuda. These businesses, created specifically to provide insurance at preferential rates, take in annual revenues of almost $1 billion.

Laws encouraging a lunar information industry could lead to even greater revenues. Instead of an offshore industry, there would be an off-planet industry providing services to the rest of us here on Earth. Sanchez envisions "teleservices" of all kinds, including teleconferencing, telebanking, teleshopping and teleeducation. Even lunar tele-tourism could be made possible with a combination of video and

DAN PICASSO

robot systems.

All this industry would require, according to Sanchez, is a few kilowatts of power and a few tons of equipment. Revenues would be re-invested, tax-free, in lunar enterprises. The result: a growing, self-sufficient lunar colony.

It may sound crazy, Sanchez acknowledges, but he adds, "If lunar habitats are to become a reality, every wild idea in the world must be tried."

—Bridget Mintz Register

YOU ARE HERE

For the price of a pocket-sized transmitter (about $250) and a $35 monthly fee, you may soon be able to determine your exact location on Earth to within 12 feet, thanks to Starfind Inc., a private California company that plans to market a satellite-based location and navigation service, with service for the western hemisphere scheduled to begin next year.

Starfind needs but a single satellite—called STAR/SAT-to determine the location of a Starfind transmitter. From its fixed position in geostationary orbit (where the satellite remains in lock-step with the turning Earth), a STAR/SAT uses 36 radial antennas, which rotate every five seconds with the satellite, to receive signals from transmitters on the ground. The signal is relayed to a ground-based Starfind command center, called a STAR/CENTER, where it is analyzed. The rotating antennas provide the necessary triangulation that allows the computers to calculate the exact location of the transmitter.

The information is then sent to the customer—for example, a trucking firm that needs to keep track of its trucks around the country, or a ranger station trying to rescue campers lost in the wilderness. The transmitter can also be used to send messages to the command center.

The first STAR/CENTER will be built near Colorado Springs, and will cost $25 million. Others are planned in Hawaii, Japan, Australia, Kenya, Spain and Uruguay.

Eventually there will be five STAR/SAT satellites providing planet-wide service, according to the company's plan. Space Services Incorporated, a private Houston-based rocket company, has been contracted to launch STAR/SATs on their yet-to-debut Conestoga rocket.

Starfind recently announced the creation of a new company, Starfind South America, which will provide the service throughout South America and Latin America. And, while other companies have been stepping forward recently to market their own satellite navigation technology, STARFIND hopes to conclude agreements for its services and products throughout the rest of the world.

— Robert G. Nichols

Galactic Events

August 26-28, University of Houston at Clear Lake, Texas. The annual Students for the Exploration and Development of Space (SEDS) conference will be held at this campus near NASA's Johnson Space Center. The conference focuses on student activities in space, and is aimed at college level students. This year's theme is "Space for all Nations." For information, write the University of Houston-Clear Lake SEDS at 2700 Bay Area Boulevard, Box 198, Houston TX 77058.

Fall 1988. Students nationwide will participate in a NASA contest to name the new space shuttle orbiter now under construction (see the article on page 44). The contest is divided into two entry divisions: kindergarten through sixth grade, and 7th through 12th grade.

Teachers and students may receive an entry packet by writing: NASA Orbiter-Naming Program, Council of Chief State School Officers, 400 North Capitol St., NW, Washington DC 20001.

Earthly Pursuits

Lasers in Inner Space

An atmospheric explorer becomes an Excalibur sword for cardiologists.

▼ ▼ ▼

By Ray Spangenburg and Diane Moser

Walk into any health food store and you'll get the latest warning about the dangers of clogged arteries. The harzards of cholesterol and other nasty substances clinging nefariously to arterial walls will be vividly described. But what about the five million Americans who already suffer from arteries clogged by fatty and fibrous deposits — the condition known as atherosclerosis?

A recent marriage of NASA technology to advanced surgical technique may hold one of the best solutions yet. Physicans at Cedars Sinai Medical Center in Los Angeles are currently pioneering a new tool for plumbing the inner space of the human cardiovascular system. Using a laser originally designed to study the upper reaches of Earth's atmopshere, they have found a way to vaporize plaque deposits on blood vessel walls.

Laser angioplasty, as the technique is called, isn't the only treatment for clogged arteries, but it may prove to be one of the best, considering that other alternatives include amputation (when severe blockage causes gangrene) and bypass surgery.

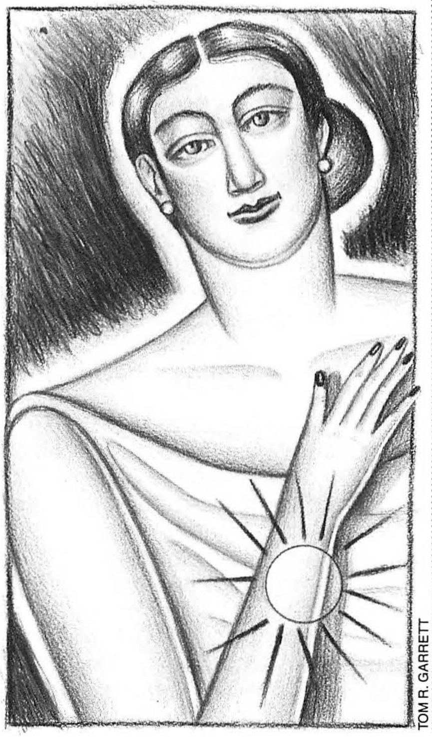
Amputation has obvious drawbacks. Heart bypass surgery means cracking open the ribs and suturing in a section of blood vessel taken from the leg, or from elsewhere in the chest wall, to route blood around the blocked cardiac vessel. Currently some 150,000 Americans undergo this treatment every year.

A technique called balloon angioplasty, using a thin catheter attached to an inflatable balloon, looked like an excellent alternative in cases where complete blockage had not taken place. But physicians like Dr. Warren Grundfest, director of surgical research at Cedars Sinai, were dissatisfied with the results. The inflated balloon squeezes deposits against vessel walls rather than removing them. So new plaque tends to form on the same sites, often within six months.

Other researchers had begun to try lasers, but those that were available seemed imprecise. Furthermore, their intense heat tended to sear the surrounding tissue. Holes could easily be burned in artery walls during treatment, and the rough, charred surface led to the recurrence of deposits.

So Grundfest and the Cedars Sinai team looked outside their field to see what other scientists were doing with lasers. They found James Laudenslager, a physicist at the Jet Propulsion Laboratory (JPL) in Pasadena, who, with his colleagues, had built a uniquely modified laser to detect atmospheric gases like ozone in the stratosphere.

It turned out that JPL's "excimer" laser, which operates at ultraviolet wavelengths, held particular appeal for the team of cardiologists and surgeons. Its controlled beam of energy could travel through fiber optics—a key factor in delivering the laser's cutting power through the tiny, twisting arterial passages to a blockage site. Unlike other lasers, Laudenslager's excimer, at a cool 104°F, would not burn the surrounding artery walls. Nor would it leave behind charred tissue. It would completely vaporize the target material, leaving no junk floating in the bloodstream. And, because it was built to fly in space, it was reliable enough for medical use.



TOM R. GARRETT

With the help of an initial $60,000 grant from NASA's Office of Technology Utilization, Laudenslager explored the possibility of using the excimer for the delicate procedure of unclogging arteries. Together with the Cedars Sinai team and fiber optics expert Tsvi Goldenberg, he refined the laser to work with a sophisticated fiber optics delivery system. The result has been a sort of Excalibur sword for cardiologists.

Here's how it works: A 1.5-millimeter catheter carrying tiny, flexible glass fibers is inserted into an artery in the arm or leg and threaded to the point of blockage. One bundle of fibers provides light. Another is tipped by a minuscule lens that connects to an external camera and monitor system so physicians can actually see the fatty and fibrous deposits that are causing the problem. Then, with enormous precision, they can pulse the excimer laser along a third set of fibers to vaporize the blockage, leaving a smooth, clean artery wall.

According to Laudenslager, who has left JPL to form his own start-up company to develop and market the technology, the main drawback is that each laser has to be manufactured from scratch. And that takes time.

No one is yet sure what the long-term postoperative effects of excimer laser surgery might be. But Cedars Sinai has treated more than twenty human patients using the NASA laser, and so far the results look good. Pending approval by the Food & Drug Administration, ten additional clinical sites exect to begin treatments over the coming months.

On human pateints, the Cedars Sinai work has been confined to "peripheral" blockages—that is, in the legs and arms. But, with FDA approval, use of the excimer laser for unblocking coronary blood vessels may begin as early as August or September. And after that, the sky's the limit for possible new applications. □

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SPACEFARERS

Remembering Challenger

Two foundations keep the flame lit in distinctly different ways.

▼ ▼ ▼

by Maura J. Mackowski

As the American space program prepares to lift off again in 1988, there are those on Earth who have committed themselves to remembering the tragedy that grounded the shuttle fleet so abruptly more than two years ago. The Challenger explosion, in their minds, is occasion to both recall the ultimate sacrifices of our space pioneers and ensure that their work goes on into the next generation.

Though Challenger memorial groups seemed to materialize by the score in the weeks following the accident, planting trees and christening school buildings in what was perhaps a natural and cathartic expression of a nation's grief, only two of the groups have managed to build a muscle-flexing level of financial and public support since then. The Astronauts Memorial Foundation in Orlando, Florida, and the Washington, D.C.-based Challenger Center Foundation are both aiming to build a better space program into the 21st century.

But talking with some of the people associated with the two groups points out some redundancy in their efforts, and hints at a bit of rivalry that simmers just beneath the surface of professional cooperation.

The Astronauts Memorial Foundation is actually a tribute to all the American astronauts who have died in the line of duty. Besides the seven on board the space shuttle and the three Apollo 1 astronauts who died in a launch pad fire in 1967, four others have perished in aircraft accidents.

The Florida group elected to memorialize the fallen with a "space mirror" sculpture, the winning entry in a nationwide design contest. Public affairs spokesperson Wanda Mefford describes the sculpture as "a highly polished granite surface, stenciled through with the names of the astronauts. The light shines through them, and at the same time the sky is reflected on the polished granite. It looks like the names are lit up in the sky."

Competing for your donation dollars is the Washington-based Challenger Center Foundation, whose avowed purpose is the advancement of space education. To this end they have launched a multi-million dollar fund-raising drive. "We're working on a $30 million program to affect the future space program," says Kerry Joels of the Challenger Memorial Foundation. "We've got a year's worth of curriculum developed, and are opening up a new center at a museum in Houston. Our plans are elaborate, ambitious and eminently doable. The lesson plans will stress science, math and critical thinking skills."

Talk to Joels for more than thirty seconds, and he'll explain for you the difference between his group and *theirs.*

"We are the only one founded by the families who survived the tragedy," he says. "We have many people who are calling, angry because they've seen our people on the 'Today Show,' 'Good Morning America' or 'Oprah Winfrey.' But they've sent their money to the Florida group by mistake."

The confusion goes both ways. Joels says he's had people calling him to find out why their license plates haven't arrived. The Orlando foundation has been raising money by selling commemorative plates and Challenger VISAs and Mastercards.

Joels questions the Florida group's expenditure of $4 million on "a granite obelisk. I knew Christa (McAuliffe) and Judy Resnick. They wouldn't have cared one whit about having their names put up on a statue."

One explanation for any bad feelings between the two foundations is the old bottom line. Asked what the difference between the two memorial groups is, Mefford's immediate and satisfied reply is "We've got four million dollars." The Astronauts Memorial Foundation has indeed been effective in its fund-raising, with the license plate venture netting $4 million in its first year. Given a five-year life expectancy for each plate, the group is looking at an easy $20 million. The charge cards and an arm-long list of corporate backers will boost their treasury sky-high.

So high, in fact, that they're not yet sure what they're going to do with their glut of dough. Wanda Mefford reports that the group has yet to come up with any definite plans for how it intends to beef up the space education programs in this country, and is just now sitting down to mull the idea over.

Meanwhile, the Challenger Memorial Foundation is raring to go, with its curriculum development plans, and will have to stop what it's doing to get back to serious fund-raising. The obvious solution is some sort of collaboration, and the two groups haven't ruled out such a pact in the future. But for now, you'll have to buy your do-dads from Florida, and your children's education from D.C. □

ERIC HANSON

ASCENT

A "rookie" gives an astronaut's eye-view of the short, fast trip into space.

BY CONGRESSMAN BILL NELSON

"Ascent phase." *That's the rather prosaic official term for the shuttle's thundering climb to orbit, the most dangerous eight minutes of any spaceflight. In January 1986, less than a month before the Challenger accident, Florida Congressman Bill Nelson had the chance to experience that violent ride for himself.*

Like Jake Garn before him, Nelson claimed his seat on the shuttle was simply an extension of his oversight duties as chairman of the House Subcommittee on Space Science and Applications. Critics saw it as the ultimate boondoggle. Either way, Nelson was the last — probably for a long time — of the official government observers invited to travel into space.

In this edited excerpt from his book, Mission: An American Congressman's Voyage to Space, *Nelson describes, with an outsider's attention to detail, the launch of Mission 61-C, which came only after a long and frustrating series of on-the-pad aborts.*

There's a certain amount of desensitizing that occurs after four scrubs. In our case, after our four trips out to the pad and the four times we'd strapped in for liftoff, the fifth trip was almost routine. Except for the few days off at Christmas, we had been in quarantine 33 days. It was Sunday morning, January 12, 1986.

Riding in the van from our quarters to the pad, one of the fellows suggested we get the "old gang" back together again in March. We could meet in Vero Beach, just a few miles south of the Cape, and work out with the L.A. Dodgers for spring training. We all shouted approval.

Despite the horseplay and the now established routine, I still felt my heart begin to beat faster as we approached the rocket in the early morning darkness. I suspected this would be it. The weather was perfect. Patrick Air Force Base had reported the outside temperature at 51 degrees. The dark sky was cloudless, the wind calm.

I had been through this procedure four times already. Yet still, the sense of personal excitement, the sense of being on the cutting edge of exploration, the sense of making myself totally dependent on the grace of God — all combined to the extent that I actually gasped for breath as the door of the van opened and I stepped out, looking up at the miraculous ship.

I had just strapped in when [astronaut] Steve Hawley stuck his head in the hatch door. He was wearing a Groucho Marx mask, the kind with the black hornrimmed glasses, huge nose and bushy mustache. He had stuck a piece of gray conduit tape over his name plate.

I burst out laughing. "Who *is* that!"

Hawley, who had the distinction of having had more scrubs than any other astronaut, said, "Shhhh! I'm trying to fool Columbia so she won't know who I am and scrub again!"

Lying on my back with my feet elevated in liftoff position, I checked my pockets. Five times I had put the same things in them. I had my voice-activated tape recorder; my pocket Bible; the regular equipment pieces NASA had issued — scissors, knife and small flashlight. I had a NASA handkerchief, but carried my own comb — the same one I had used to comb my hair in the active TV camera

January 12, 1986: Columbia rises into the pre-dawn sky with seven people, including Bill Nelson, onboard.

ALL PHOTOS: NASA

lens. I was also wearing my hard contact lenses. The doctors did not think I would have any trouble with them in space. They took care to remind me, however, that when you drop a contact lens on Earth the only place you have to search for it is on the floor. If you drop it in space, there's no telling where it might float off to.

I smiled when I realized I had automatically reached back to check my left hip pocket. There was no need to carry a wallet into space. Even American Express cannot give you credit once you leave the state of Florida—that is, if you're traveling straight up. Nor was I wearing the ever-present plastic security badge all NASA personnel are required to display on their shirt, jacket or blouse. There was a standing joke that the astronauts had better wear their badges when they climbed aboard the shuttle or the security guards would not let them on.

Bill Shepherd, our Cape crusader — the astronaut designated to make the final checks — talked us through the radio checks. Bill had been in the shuttle since midnight, checking all the switches to make certain they were in the right configuration. His final task before leaving the shuttle was to do a voice communication check to make sure we were all on the right channels. I reached down and touched a button on the black box clamped to one of the straps on my flight suit. It activated the microphone in my helmet so I could use the intercom.

"Okay, Steve, this is PS-Two. (That was my designation, short for Payload Specialist Two.) How do you read?"

"Loud and clear, PS-Two," Hawley answered.

Next, Bill Shepherd talked us through our communication checks with Fred Gregory, at Mission Control in Houston. Fred went through each crew member in turn, checking us out to make certain we could both hear and be heard.

"Good morning, Fred," I said. "This is

As we cleared the tower I could see the ground illuminated by the fire of the motors. The next view from the window was darkness, then the lights of Cape Canaveral.

PS-Two."

"Loud and clear, Congressman," he replied.

Bill was the last one to leave, climbing out of the hatch and waving goodbye. The hatch door closed. This time the latch caught the first time. I looked at my watch. It was 5:01 A.M. We had one hour and fifty-four minutes to wait.

The night before, as we had on most of the nights before our scrubbed launches, we had eaten together in the dining area next to the crew quarters. Then we headed for the sauna before taking a shower and going to bed early. As usual, the conversation turned to all the things that could go wrong.

Danger was not new to these men. [shuttle commander] Hoot [Gibson] and [pilot] Charlie [Bolden] knew that every time they strapped into one of those powerful military jets, they were taking on almost the same odds. Therefore, that Saturday night, sitting in the sauna, the same positive spirit prevailed that I had noticed before each of the other flight attempts, but this time even stronger.

I knew we could make it if we lost one of the engines on liftoff. "But what happens if we lose two of the three engines?" I had once asked Hoot.

"We're in the water," he had replied matter-of-factly.

The critical point, as far as the main engines were concerned, was seven and a half minutes after liftoff. Although the main engines cut off at eight minutes and thirty-six seconds into flight, if they worked through the seven-and-a-half-minute mark, the shuttle would still go on into orbit — or we could pick an emergency landing site. We would not drop back into the ocean. I made a mental note to check my stopwatch at seven and a half minutes after liftoff so I could breathe more easily.

Perhaps because this was the fifth launch eve I had gone through in less than a month, I didn't have any problem going to sleep. I had set my wrist alarm to go off at 2:20 A.M., a few minutes before the normal wake-up call on launch morning.

As soon as I was awake, I dashed for the bathroom down the hall. The Columbia crew had a corridor to themselves on the third floor of the Operations and Checkout building [at Kennedy Space Center]. Bob Cenker always beat me to the bathroom. That morning our timing was perfect. Cenker showered while I shaved, allowing me to get into the shower by the time Franklin [Chang-Diaz] and [George] Pinky [Nelson] arrived in the bathroom. We dressed casually, then gathered in the dining area for breakfast. A few other NASA people had arrived by that time, and the NASA TV cameras were in place, taking our pictures as we ate. After breakfast we put on our lightweight flight suits, then gathered for the morning weather briefing.

As usual, the briefing was extensive. The commander and pilot sat with their lap boards, writing down all the usable data. This was necessary to determine things like which runway to use at alternate landing sites, what to expect if we aborted on takeoff and had to do an RTLS (return to launch site), winds aloft and ground wind speeds. I had to keep reminding myself that the shuttle was not an airplane. It did not have an engine to be used on landing. It was nothing more than a huge, heavy glider that had the aerodynamic ability of a large, flat rock.

Jet pilots, and especially astronauts, have a reputation for being daredevils. Even though Hoot was studied and deliberate in everything he did — actually supercautious — he had a daredevil streak in him as well. I found out during training that some fighter pilots consume a drink called a Flaming Hooker, which is a lighted Drambuie. The procedure is to pour the drink into a glass, set it on fire, swallow the entire contents while it is flaming, then set the glass back down — the fumes still burning. I had not seen this done, but everyone said Hoot could do it. Fighter pilots seem to be a special breed.

Back in the shuttle we went through the multitude of checks that are part of the liftoff procedure.

I could hear the air blowing in as they pressurized the cabin from the outside. We went through the initial cabin pressure leak check, and everything was fine. During the next hour, as the checks continued, I spent a good bit of time dictating my thoughts into my little handheld tape recorder. At T-20 minutes, I felt movement on the orbiter as they configured all the switches, checking the flight surfaces and gimballing the engines. At T-9 the launch director, Gene Thomas, came on the air.

"It looks like it's a 'go.' Our best to the best flight crew we've had around here in a long time."

"That's because we've been around here a long time," Steve retorted.

A minute and a half later, I imagined a slight scraping outside the orbiter. By twisting my head to look outside the window, I could see the access arm retract. Now we were standing alone on the pad. I was reminded just how complicated the space machine was. We were, in pilots' lingo, going to "push the envelope."

At four minutes before launch we lowered our visors. I thought of Grace and the children on the roof of the Launch Control Center watching this spaceship poised to ignite toward the heavens. They and everyone else not directly involved were kept a good three and a half miles away, in case of explosion.

Thirty-one seconds before launch, we switched to the onboard computers. I pulled back my gloves to glance at my watch. We had been given a choice as to the type of gloves we wanted to wear for launch: a light tan doeskin glove, or the greenish-gray standard Air Force glove that is fire resistant. I was wearing the Air Force glove and pulled back the cuff so I could punch my stop watch at T-0.

The engines ignited at T-6.6 seconds. I felt a powerful surge of energy, even though there was no perceptible movement, since we were still bolted to the pad. I knew it was possible, still, for the automatic sequencer to shut down the engines. Steve Hawley had been on a previous flight that had gone into automatic sequencing, and the computer had shut off the engines at T-2 seconds — four and a half seconds after the engines had ignited.

I knew it could happen to us, but I didn't

expect it. During this time, tens of thousands of gallons of water were being dumped on the exhaust in the huge concrete exhaust basin at the base of the rocket. Without this precautionary measure to suppress the acoustic shock wave, the shock would destroy the shuttle.

Now the entire ship was vibrating, and the roar of the rocket engines was almost deafening as the engines thrust against the restraints. Yet, Columbia was still strapped to the ground.

Hoot Gibson was talking us through the liftoff: "There go the engines."

At T-0 I punched my stopwatch. At the same instant there was a jolt and a huge roar. I felt a tremendous kick, a surge of energy as I was pinned on my back: "Okay, the solid motors have ignited," came Hoot's voice. "We're climbing."

I pulled my hands back up against my chest and turned my head to the left so I could see out the window. Everything was gray. It was the gray steel of the tower, and I could see it sliding by the window as we began our ascent.

I was astounded at how quickly we were moving, slow at first then faster with each second. It took only four seconds to clear the tower, the engines burning furiously. As we cleared the tower I could see the ground illuminated by the fire of the motors. The next view from the window was darkness, then the lights of Cape Canaveral.

Ten seconds into launch, above the roar of the engines, I heard Charlie Bolden say, "We're starting our roll maneuver."

In order to get into the proper flying attitude, the orbiter needed to change position. That meant as soon as we cleared the tower, the computers sent us into a ninety-degree roll maneuver that turned us so our back was facing east. Now we were climbing straight up, strapped to the huge rocket.

Suddenly, over my earphones, I heard the words that made my skin prickle.

"We have a malfunction."

It was Charlie Bolden's calm voice talking on the intercom.

"We have a helium leak."

He was talking to the crew, not the ground.

Even though I could not see Charlie, who was eight feet above me in the separate flight deck compartment, I knew what he was doing. There was no panic. He was efficiently reconfiguring the switch — going by the book.

During the next few seconds he calmly talked us through a potential crisis — a crisis I later discovered was sufficient to have shut down one of our three engines while we were ascending straight up. As this was going on, Hoot was talking to Mission Control in Houston, which had taken over from Launch Control at Kennedy the moment he had cleared the launch tower. Charlie, however, was too busy trying to stop the helium leak to talk to Mission Control. That was not done until the emergency was resolved, the apparent leak electronically blocked off, and the danger past. Then Charlie pushed the button that put him in touch with Mission Control and reported what had just happened.

A few seconds, I discovered, can seem like a lifetime when your safety hangs in the balance.

The emergency underscored that it was not the people on the ground who flew the machine; it was the commander and pilot. They were at the controls. Even though everything was programmed by computer, when something went wrong they had to know what to do. After having spent hundreds of hours in the simulator, working through every possible type of emergency, both Hoot and Charlie knew exactly what to do when the gauge on the instrument panel went wild, showing helium was leaking in the spacecraft.

Thirty seconds into the flight, we entered the stage of maximum dynamic pressure on the spaceship, or "Max Q," as NASA calls it. Even though there was no sensation other than the vibration and noise, it was at this point that we passed through the sound barrier, gaining speed at an incredible rate. However, since we were still in the thicker, lower atmosphere of the Earth, full speed during Max Q could destroy the spaceship. It was impossible to control the thrust of the savage solid rocket boosters, which were burning violently on each side of the spaceship. But it was possible to control the thrust of the three main engines located in the tail of the orbiter. As we entered Max Q, the computer throttled the main engines back to 65 percent of their power. This condition of stress would last until we broke free form the dense lower atmosphere.

Coming up on seventy thousand feet, we heard Hoot's calm voice,

"Throttle up and go."

We had left Max Q. The engines were being throttled up to 104 percent, or full power.

I was surprised how quickly time now began to go by. At two minutes and eight seconds into the flight, there was a loud thud as pyrotechnic charges blew the bolts and separated the solid rocket boosters from the external tank. I was startled by the huge jolt as they broke loose. Suddenly, it was quiet as the SRBs, still burning fiercely from their tails, slipped away. Later, the big parachutes opened, and they began their long fall back into the Atlantic Ocean, where they would be recovered and used again.

For a moment I was puzzled at the lack of noise; then I remembered we were flying faster than the speed of sound and the exhaust of the main rocket engines was behind us. Our speed was increasing toward our maximum of 17,795 miles per hour—which would be our orbiting speed around the Earth.

At six and a half minutes, the G forces began putting powerful pressure on my body. I glanced at my watch and saw the digits change as we passed the seven-and-a-half-minute mark. I felt a sense of relief. Now, even if two of the main engines cut off, we could make it to one of the emergency landing sites without having to ditch in the ocean. All three of our engines kept on humming.

The G forces on my body continued to increase until there were three Gs of pres-

continued on page 57

Nelson, Bob Cenker and Franklin Chang-Diaz on their way to the launch pad.

It's 6:00 A.M., Houston time. Early morning vision blurs the eerie sight of your own arms floating in front of your weightless body. Time to peel out. You unzip the lightweight material of your sleep sack, where you've been hanging on one wall of your private crew quarters. The opposite wall, with its inset data console, bumps against you as you float out of bed. Even after nearly two months of calling it home, the narrow, windowless "room" still feels cramped. You steady yourself with one foot against the wall, thinking back to the video conference you had last night with your family. Their photo, stuck to the wall by your monitor, smiles back at you as you call up the day's schedule at the console. Another day on the space station has begun.

If you can believe it, says former astronaut Bill Pogue, "Compared to Skylab, the space station will be Hilton class." One of three U.S. astronauts who spent nearly three months aboard the orbiting Skylab in 1973-4, Pogue, along with his crewmates Gerald Carr and Ed Gibson, know probably better than anyone else what it will be like to live and work on the NASA/international space station of the 1990s.

The astronauts of Pogue's era were nearly all test pilots, used to cramped quarters and all but immune to claustrophobia and confinement. The space station will be different. It will house international crews from varied cultures, with different backgrounds and objectives, for weeks or months at a time. Even if the crew quarters seem spacious (about 125-150 cubic feet) by Skylab's coffin-like standards (84-85 cubic feet), the total free space onboard the station will be minimal.

The space station, when it finally begins to take shape in the late 1990s, will more closely resemble a couple of cramped cylindrical house trailers joined by tinkertoy-like nodes than it will a luxury hotel. The challenge will be to make it a livable, human place to work, reflecting not just the crew's ability to survive adverse conditions, but also their humanity. And all of this without raising construction costs.

As envisioned now by NASA and its contractor Boeing Aerospace, living quarters for the station's crew will take up one small module (called the "Habitation Module" in NASA-ese). Another module will house the computers, centrifuges and other laboratory equipment used for ongoing manufacturing and scientific experiments. Each of these cylindrical modules measures about 14 feet in diameter by 45 feet, the maximum size that can be carried into orbit inside the space shuttle's cargo bay.

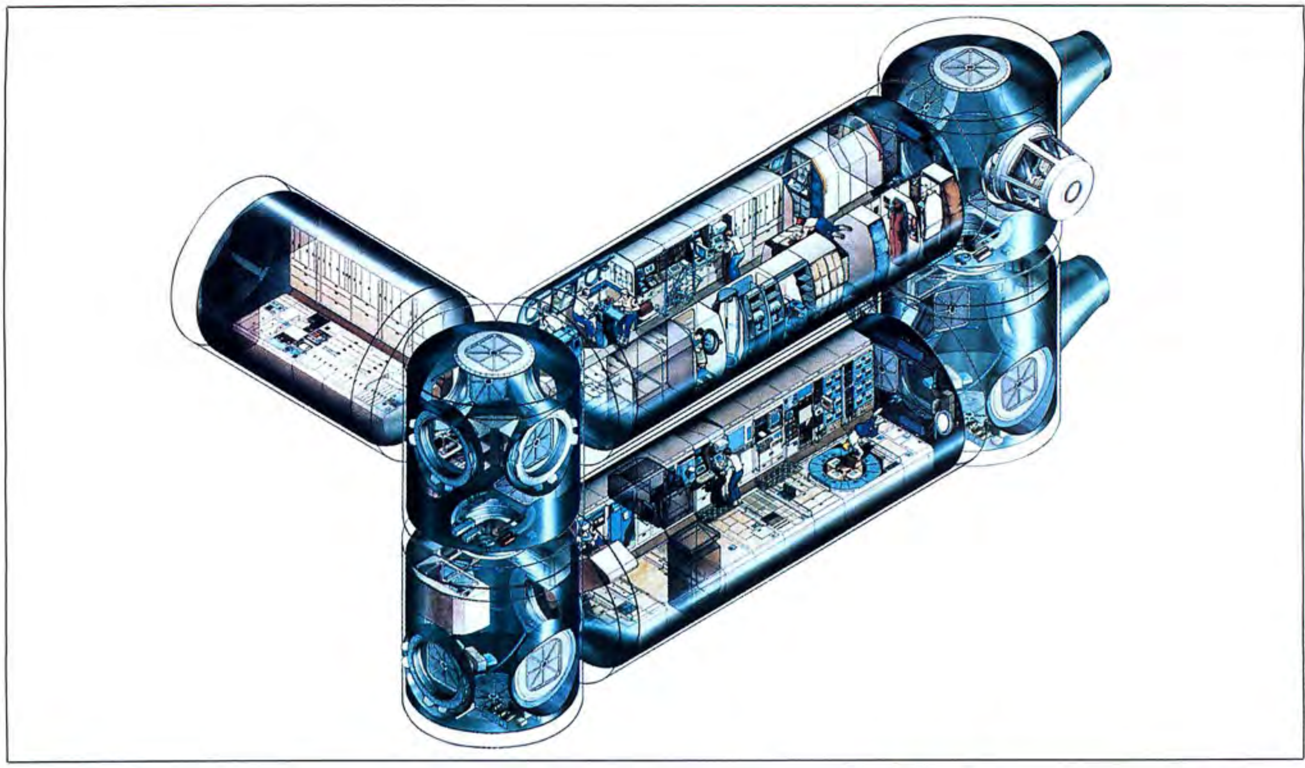
The perimeters of the cylinder will be used for stowing equipment and supplies needed by the eight-member crew for a 90-to-180-day tour of duty. That leaves a

BOEING AEROSPACE

Adding a human soul to NASA's new machine.

AT HOME ON THE SPACE STATION

BY RAY SPANGENBURG AND DIANE MOSER



volume of some 10 feet by 11 feet by 6-1/2 feet for the wardroom, the largest open area in the Habitation Module—not very big for a crew of eight, even by crowded urban standards.

The Habitation Module's trailer-like space, so the plan goes, will be divided into three major areas: the "quiet zone" at one end (containing crew quarters), an "active zone" at the opposite end (for the wardroom, galley and exercise area), and a "buffer zone" between (with more data consoles, a shower, toilet and washroom).

Any way you look at it, the station will offer few opportunities to get away from it all. And your crewmates' companionship could wear thin. That's why NASA is paying close attention to the issue of private crew quarters.

"I want astronauts to want to go back," says NASA socio-technologist B.J. Bluth, who is concerned that valuable training and experience will go down the drain if space crews feel so burned that they don't consider going back for seconds. Pogue and Carr, as consultants to Boeing, are joining with NASA experts like architect Marc Cohen and environmental psychologist Yvonne Clearwater to see that the space station really is a nice place to go back to.

As a member of the crew, you'll get your own private "stateroom" to call home. It will measure about 84 inches high, 42 inches wide and 39 inches deep—not much bigger than a closet. A slightly curved door will extend into the corridor, according to Boeing's lead architect, Brand Griffin. Though most people will be able to touch all four vertical walls from the center of the compartment, it will seem a little bigger than it would on Earth, because you can float around the ceiling as well as the floor. An additional area, about half as wide, will be available for stowing your belongings.

If Yvonne Clearwater wins the day, you'll have a lot of options for making that space truly yours. "How much can it cost to decorate a telephone booth?" she asks, pointing out that crew members might easily foot the bill for personalizing their own quarters if cost is a problem, as it always seems to be for NASA.

"Your crew cabin," she adds persuasively, "is the only place you can humanize, territorialize and personalize anywhere on this completely metal,

machine-dominated, often artificially intelligent environment."

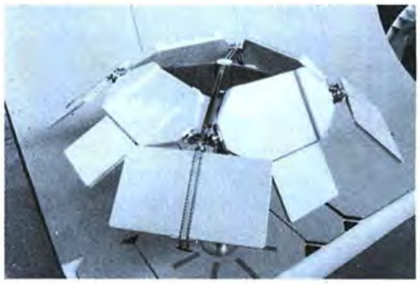
While many astronauts maintain that they don't care about color or aesthetics—the "just paint it gray and I'll live with it" school of thought—Bill Pogue warns that a short-term Shuttle mission is a lot different from digging in for a three-month stint. "They may think that [gray is fine]," he says, "but once they get up there, they'll change their minds."

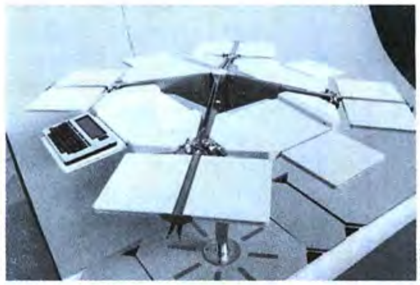
The evidence, both scientific and intuitive, clearly suggests that the ability to change one's environment is important to a sense of well-being. Paintings hung on a wall, family photos and pictures of natural settings can help maintain that all-important link with Earth and reinforce the sense of home.

"If you're going to go [into space] as a representative of your species—one of the few people who really gets to go on these prolonged trips, I think it's your responsibility to carry your humanness with you," says Clearwater, seated in her (not by choice) windowless office at NASA's Ames Research Center near San Francisco. The walls, dappled with photos, objects of interest and perimeter lighting, combine with her own personal energy to create the kind of human touch she says is necessary for space travelers. "It's your responsibility to take care of yourself by setting up an environment you really feel you can live with," she adds.

Chances are, if you're a crew member on the space station, you'll spend much of your free time and probably some of your work time literally "hanging out" in your quarters. Aboard Skylab, say both Pogue and Carr, the astronauts spent a lot of time in their sleep sacks. It was the best place to listen to music or to read a book, since the sleep sack keeps you from floating freely around. It left both hands free for turning and holding down pages, always something of a problem in zero-g. And people working in confined quarters in harsh terrestrial environments develop a greater need for private time (choosing to spend up to 60% of their free time alone, according to one study).

LONI SPECTER





NASA

Opposite page, top: The U.S.-built portions of the space station will include a "habitation" module (top center) and a laboratory module (bottom center). The logistics module at far left and the "nodes" connecting the cylinders will add storage space.

Opposite page, left: The "active zone" of the habitation module (foreground) will be for exercise and group activities.

Opposite page, right: Getting away from it all in the crew compartment.

Above: A wardroom table could seat a single astronaut or serve as a conference table for the entire crew.

Left: Psychologist Yvonne Clearwater at the console of a space station mockup at Ames: "I think it's your responsibility to take your humanness with you."

Architects and designers like Cohen of NASA/Ames and Boeing's Griffin envision space station crews using their quarters as offices, too. The data station on one wall of the stateroom makes this feasible. The TV monitor can also be used for viewing videotapes or for communicating with Earth-side family members. And, says Griffin, the private areas will be grouped in pairs, with an option for a Dutch door between them if two crew members want to work together. A married couple on the station might even want to take out the door altogether and share the entire space.

You glide up to the shower door as the clatter of your crewmates fixing breakfast echoes along the short corridor. It's 6:05. You didn't sleep well last night. Someone took a late night ride on the exercise bike off the wardroom and the vibrations throughout the module jostled you awake. You grab a hand hold to wait your turn as your crewmate finishes up her 5:30 shower. After the last traces of water are mopped up, she opens the door and waves as she pushes off down the hall.

Inside, you brace your feet against the sides of the stall and position one of the suction-cupped hand holds in a comfortable position, adjusting the air flow temperature with one eye on the digital readout. With the water wand you wet one arm, shut off the flow and lather up. After rinsing, you vacuum the water droplets off your arm with the vacuum wand. Then you repeat the sequence for your other arm and the rest of your body. Finally you vacuum the stall, chasing down each floating droplet of water. A thorough towel-down finishes the job. Free-floating water can be a nuisance as well as a hazard to experiments, so the process is essential. The entire routine takes 35 minutes. Just enough time left to dress and head for breakfast.

Bathroom facilities on the space station have received considerable thought from the NASA/Boeing team of architects, psychologists and engineers. On Skylab the shower was an ingenious collapsible plastic enclosure that folded out of the way when not in use. At least it seemed ingenious on the ground. In space it was a pain. It took too long to set up, too long to clean up, and too long to fold up. The astronauts finally settled for sponge baths for most of their mission.

As for the toilet, or "waste management system," as NASA prefers to call it, neither Skylab's (which didn't accommodate women) nor the shuttle's design will work for the space station. According to Griffin, "It has to be more reliable and less complex, with easier maintenance and higher capacity."

Current plans call for only one toilet in the Habitation Module ("That's got to call for a lot of cooperation," comments one NASA planner). Another one may be located in the nearby Laboratory Module, just a quick journey away through a connecting tunnel.

Plans for the wardroom and galley call for a minimal amount of housekeeping—time in space is always costly—and maximum congeniality and flexibility for the station's largest gathering place. A VCR and monitor set-up will make it the ideal place to enjoy movies together or view instructional tapes. And Earth-watching out the two 20-inch windows is sure to be high on everyone's list of off-duty pastimes. (Bill Pogue puts windows at 12 on a scale of 1 to 10 in terms of entertainment value.)

Meals, though, may be the wardroom's most important social occasions. Even on the much shorter shuttle missions, crews usually eat together. The astronauts' busy work shifts mean that meals are the only opportunity they have to compare notes, share thoughts and impressions, and generally enjoy a social life.

"I want astronauts to want to go back to the space station," says NASA sociotechnologist B.J. Bluth.

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Submarine crews, Antarctic teams and Soviet cosmonauts all agree that in a limited sensory environment, variety and quality of food take on great importance. With no refrigeration and an unsatisfactory microwave, Shuttle crews tend to "camp out," using mostly dehydrated foods, which they rarely cook or heat. But the space station will have a freezer, refrigerator and both microwave and convection ovens.

U.S. Department of Agriculture technologists are perfecting a method of keeping fruits and vegetables fresh through special packaging. And a technique for stabilizing food thermally may make it possible to store on shelves the sort of prepackaged meals now available in the supermarket freezer.

As you glide into the galley area, you pick up your tray from its storage area and pop your breakfast of scrambled eggs and sausage, ordered the night before, into place. You inject coffee, tea, or maybe even soda from a special zero-gravity dispenser into your covered beverage container, which you fit into a slot on the tray to keep it from drifting away as you push off toward the wardroom table. Before starting to eat, you hook your foot into a restraint on the floor to stabilize your body, which naturally takes on the "S"-shaped posture peculiar to weightlessness.

What good is a table in zero-g? Since you don't have to hold things up (they won't drop), do you need to have a place to set things down?

Yes, says Cohen. A flexibly designed table could solve a lot of problems aboard the space station. It could lessen the "camp-out" atmosphere and make the wardroom seem more like home. Fasteners on the table could hold meal trays in place and free both hands for eating as you wrap your lower leg around a special restraint or slip your toe into a foot loop. In zero-g, the body hunches slightly forward, changing the angle of your line of sight.

Cohen's wardroom table tilts to any angle to accommodate people of different heights, doing lots of different tasks. It can fold out to provide a flat workplace for a personal computer and keyboard, or it can double as a conference table for the entire crew.

Strangely enough, one lesson learned from Skylab is that, even with easy access to all the surfaces of a room, the human mind needs a sense of up and down. "In Skylab," says Carr, "one compartment would have an up direction. Then, as you moved into another compartment it could have several up directions different from the one you came out of. So there was always that little instant of disorientation."

Humans are creatures of reason, with a resilient intelligence. But ultimately, we are Earth creatures. On Earth, as Clearwater points out, the sky is light and the ground is dark. Even in the darkest part of the ocean there is an "up" and a "down," and we instinctively expect that from our environment. So the space station will have a built-in "local vertical," possibly cued by a lighter colored ceiling and a darker floor, so that floating astronauts can orient themselves quickly and easily.

We are also creatures who have always produced art, as far back as the Cro-Magnons who etched drawings on the cave walls at Lascaux, France.

"Art is one of the things that links us to our humanness," says Clearwater. "It's one of the things that links us between cultures. And it's one of the things that links us to the Earth. The farther we go away from Earth, the more I think we need to carry certain links back with us."

Her dream, she says, is that some day the space station will include an international art gallery on its walls. Donated art, specially prepared to fly in space, could carry our humanness one step further, inside our bare-bones tin cans in space. □

Ray Spangenburg and Diane Moser are freelance science writers in San Francisco.

OCEANS ABOVE

There are plenty of oceans beyond the Earth. You just have to know where to look.

BY CHARLES R. PELLEGRINO

There is a place on Earth with no sun in the sky—so black as to be brilliant; evil appearing and cold. Very cold indeed. Peering down through a robot's eyes, you see what looks at first glance like a rose garden grown out of control.

COMSTOCK INC./TOM GRILL

But these aren't red-tipped flowers. They are giant, deep-ocean worms that live by inhaling sulfides from within the Earth. Lacking any trace of a digestive system, they live directly on the cracks in the world, manufacturing their own food and evolving along strange paths, without the benefit of solar energy.

Down here, deep in the ocean, our robot eyes see pillars of hardened lava capped with crinoids—creatures that should have been extinct millions of years ago. Near a live volcanic spring, bacteria thrive so well on the sulfides that they literally carpet the bottom. Crabs and fish graze on them—an oasis in the deserts of the deep.

Over there is a sliver of metal about two feet long, a piece of scrap dropped by a ship, perhaps. But when our little robot moves in for a closer view, the thing flutters away like a bird. And something over there looks like a honeycomb built by bees. Certainly there are no bees on the bed of the Pacific; yet someone—it's anyone's guess who—has put hexagons everywhere.

You can spend weeks on a research vessel, as I have, looking at live pictures from two miles under the ocean. You can even go there directly, in the Woods Hole Oceanographic Institution's inner-spaceship, the *Alvin* submersible.

And always your mind wanders up from Earth, toward Jupiter and Neptune and their attendant moons, and the oceans that might exist there. The oases of life on the Pacific floor belong to Earth, but they may also be windows on other worlds. And they raise the persistent question of whether we will find life in watery places beyond our own planet.

One of the most likely sites for an extraterrestrial ocean will be studied at close range for the first time next year. On August 24, 1989, Voyager 2 will hurtle past Neptune and its large moon Triton, the spacecraft's last stop on a 12-year mission of planetary exploration.

University of Hawaii researchers have confirmed with Earth-based radar that the surface of Triton seems to be awash in an ocean of cold liquid nitrogen. In the summer of 1989, we may look down upon a world very similar in appearance to the Earth. But nothing will be quite as it appears. The continents will be ice. The snowfields and the glaciers will be methane. Volcanoes will be erupting water from the interior.

The core of Enceladus is literally a world within a world, a planet so small that a submarine could take you all the way around its 300-mile circumference in a single day.

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If Voyager detects these water volcanoes, Triton's most astonishing feature will be the magma chambers that feed them. The primary force that would keep ice warm enough to flow as liquid at this great distance from the Sun would be frictional heating caused by the satellite's chaotic orbit around Neptune. Though it whirls around the planet at nearly the same distance that the Moon circles Earth, Neptune is nearly seventeen times more massive than Earth, and Triton circles five times faster than our Moon as a result. It also circles backward, east to west, in a direction opposite Neptune's rotation.

The tides of Triton must put the Bay of Fundy to shame. Neptune pulls the satellite nearly two feet closer every year, and ultimately Triton will crash down in pieces on the planet. Physical models suggest that the current rate of internal heating due to this tidal action is enough to sustain layers of molten ice, or water, inside Triton, if the interior was once melted by something else.

The heat that could have created liquid oceans inside Triton might be left over from the original accretion of the Neptune-Triton system from chunks of bombarding material. Or, the decay of radioactive elements in Triton's core could be another source of heat, which would result in eruptions of basaltic lava on the sea bed.

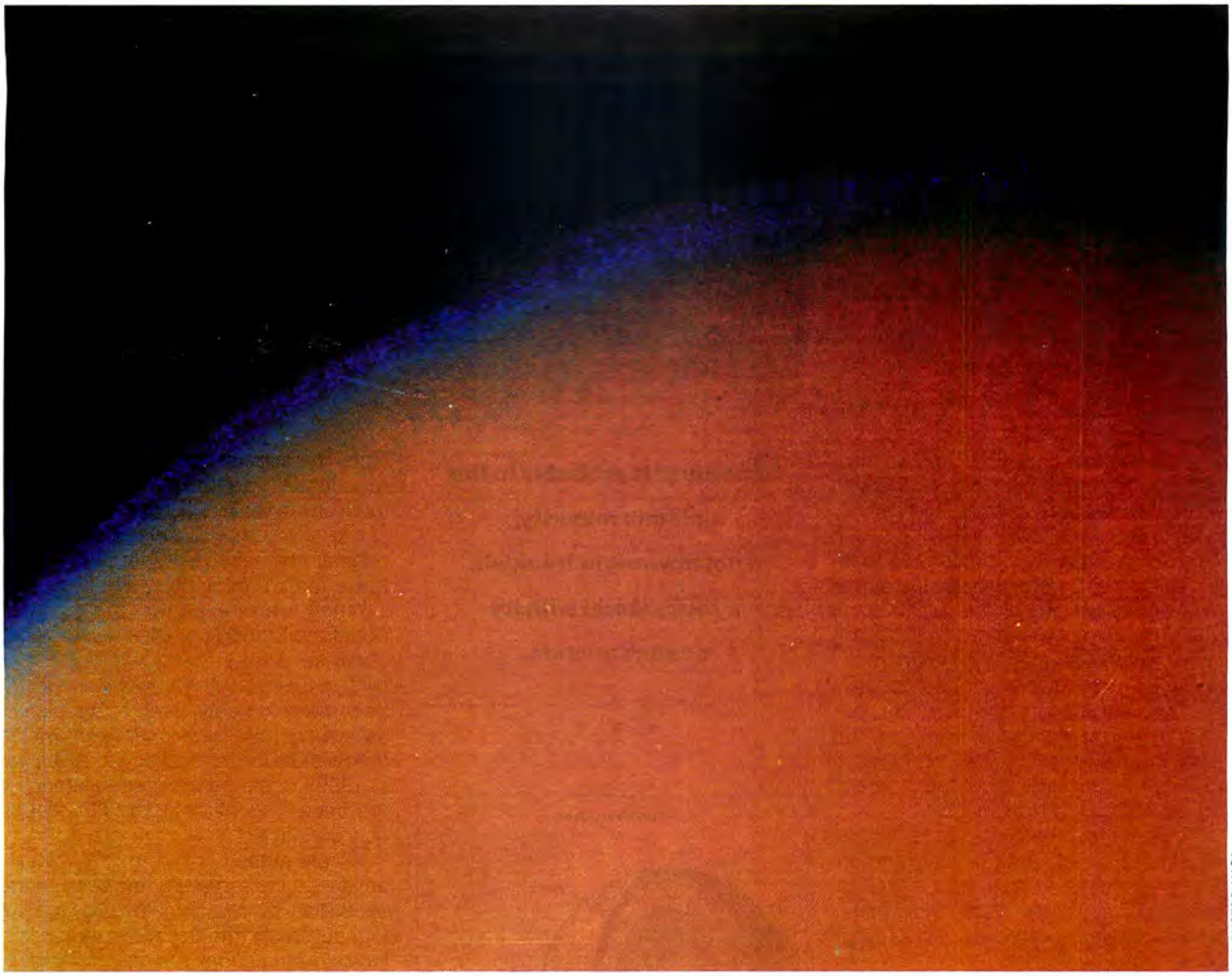
If there was enough early heat to result in a modern Tritonian ocean beneath the ice, one can only wonder if there is life down there. This much is certain: where there are sulfides and water—and a quick look around the outer Solar System tells us that sulfides and water are everywhere—there are infinite possibilities. We look out upon whole new worlds full of questions. All of them are fun to think about.

With (probable) nitrogen oceans lapping at its shores, and with watery oceans beneath its continents, we can speculate about the development of life both above and below Triton's surface, bringing to mind the Buddhist concept of different planes of existence. A "fish" erupted up through a water volcano would die painfully, freezing solid within seconds. If, before it died, it were to embrace an inhabitant of Triton's surface, the touch of this lava dweller would feel like molten lead.

In the sky overhead, beneath the thick clouds of Neptune, (which are all we can see of this giant gas planet from Earth) is an icy shell. Beneath Neptune's shell could be the deepest ocean of all, but there is no point in contemplating life on its floor. Even if there are volcanoes and hot sulfide springs, there would be no oases for life. More than 2000 miles of overlaying water preclude biochemistry.

The pressure at the bottom of the Neptunian sea would be so great that carbon, one of the most abundant elements in the Solar System, could behave in only one

Saturn's ice moons Enceladus (above) and Titan (opposite, with its hazy atmosphere shown in false color) are both possible sites of underground oceans.



ALL PHOTOS: NASA

way, by crystallizing. In Neptune's ocean, large clean crystals would grow a brilliant sapphire blue. Standing on the surface of Triton, looking up at Neptune, you might reflect that beneath thousands of miles of atmosphere and ocean is a world of rock and metal, slightly larger than the Earth, whose outer crust is made of diamond. Some of the stones must be larger than office blocks—but no submarine you can imagine would be able to get at them.

Moving on to a nearer, more hospitable ocean, we would come to Saturn and its small ice moon Enceladus. Since Enceladus has no atmosphere, water erupted through breaks in its frozen shell would flash to vapor. Some would fall back as snow, and the rest would escape into space—which explains, perhaps, why Enceladus' surface reflects as much sunlight as fresh-fallen snow and why trillions of twinkling ice crystals occupy the moon's orbit, forming Saturn's outermost ring.

Enceladus is in the middle of a gravitational tug-of-war. On one side is Saturn. On the other side are Tethys (a 652-mile wide moon that sometimes sweeps past Enceladus at very close range) and Dione (a 695-mile wide satellite that approaches within one half the distance separating the Earth from the Moon). Despite the fact that Enceladus could fit comfortably within the borders of New Mexico, it is one of the most geologically active bodies in the Solar System.

We know from analyses of Voyager 2 images that this second moon of Saturn has been reshaped by volcanic forces throughout 4.6 billion years of history. Even as dinosaurs roamed across Montana about 100 million years ago, craters on Enceladus were split in two by upwelling crust. In terms of geologic time, 100 million years ago is last Tuesday about lunch time, so it is highly unlikely that such activity has since ceased. Deep down, these tidal pulses should have melted the ice to create an internal ocean.

Measurements of Enceladus' density indicate that it has a rocky core some 95 miles across. This core is literally a world within a world, a planet so small that a submarine could take you all the way around its 300-mile circumference in a single day.

If, during Enceladus' long history, there existed sulfide oases on an ocean floor, we can speculate whether they may have supported biological activity, even living cells. Living on or near a rock surface with an area of only 47,000 square miles (compared to the Earth's 300 million square miles), however, they would not have experienced the isolation and subsequent branching events that have characterized terrestrial evolution.

Considering also that the food supply is likely to have been small, limited perhaps to an acre of sulfide seeps here and there, life might never have gotten to the jellyfish or crab stage, even with all of Enceladus to experiment with for 4.6 billion years.

The largest of Saturn's moons, Titan, appears to have a rocky core nearly as large as Earth's moon. Given enough internal heat, this could be overlain by layers of ocean and ice. If so, breaks and grooves in the crust should be visible. But identification of any such features will have to await radar mapping probes that can see through the thick clouds that obscured Voyager's view of the surface in 1980.

Titan is a favorite spot for speculation about life elsewhere in the Solar System, due to the complex organic molecules known to exist in its atmosphere. Titan may even have surface oceans, not of water but of mixed ethane and methane. But if seas of

Our Earth is probably in the galactic minority, if not downright freakish: a rocky world with its oceans outside.

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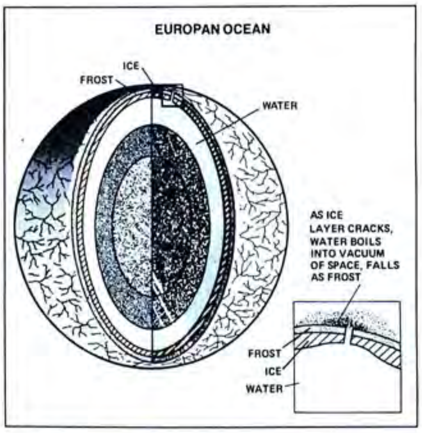
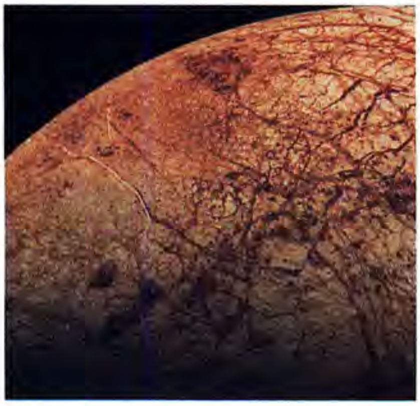




Jupiter's moon Europa (above and opposite) may have the most accessible ocean of all, beneath its thin shell of cracked ice.

water exist under the icy surface, we may well reach nearby stars before we discover them; the satellite's shell is at least 100 miles thick.

Closer in to the Sun, Jupiter's second large satellite, Europa, seems to have a more accessible ocean. Four water volcanoes appear to be linked to a bright (snowy?) spot on Europa's southern hemisphere. Glancing over its shoulder as it departed the Jupiter system in 1979, Voyager 2 caught a glimpse, from very far away, of what looks for all the world like a plume rising 75 miles above the crescent moon—a snowstorm in space.

There are no mountains or crater rims on Europa, which is slightly larger than Earth's moon. Its surface is flat and filled with cracks, as if it were warm plastic constantly in motion, with every hill sinking under its own weight.

Europa will be high on any 21st century explorer's list of destinations. Robot submarines mounted on nuclear reactors (cooled by the ice they melt) could descend through thin spots in the crust. We may even want to venture there ourselves. A new generation of rockets that exist today only on drawing boards would be smaller than an average-sized coffee table. Arranged in clusters, they will be capable, in about twenty years, of propelling something as large as a space station all the way to Jupiter in only a few weeks.

Of all the new oceans discovered recently in the Solar System, the one inside Europa seems to be the most accessible, because the ice cover is thinnest there. In 1985, I made the suggestion that we may one day bring the Woods Hole submersible *Alvin* to Europa. The idea met with such encouraging noises from both oceanographers and space scientists (who normally view each other as adversaries competing for the same limited funds) that I am inclined to believe it will actually occur.

Though such a mission is more than two decades away, the three-passenger *Alvin* (small enough to be contained in some living rooms) will not be obsolete by that time. The submarine is constantly being rebuilt and updated. Presently, only a robot arm, a few hydraulic pumps and one or two wires remain of the vehicle that was originally launched in 1964. By late 1988 these, too, will be gone.

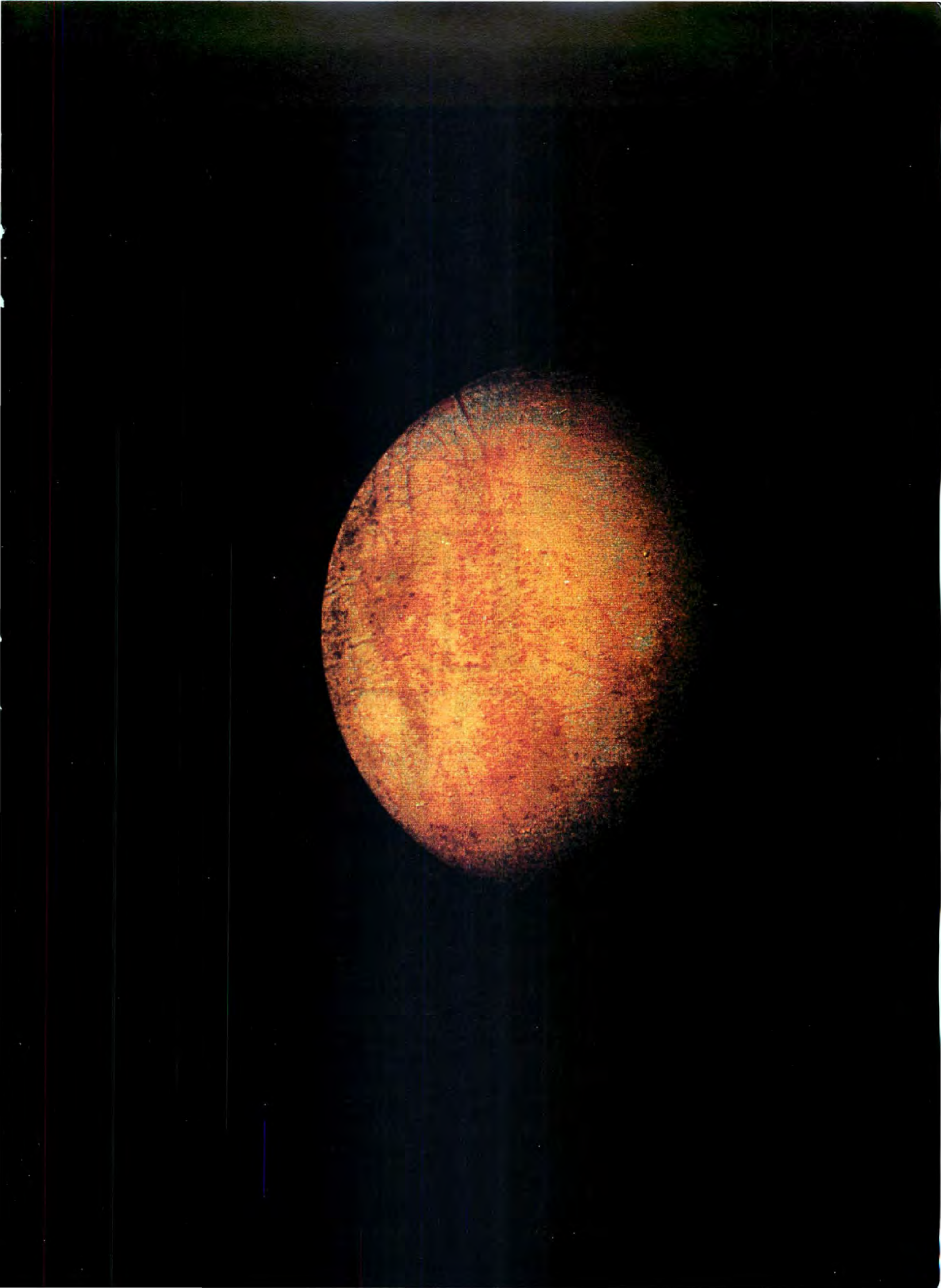
When future explorers are ready to penetrate Europa's shell, it would be no surprise if they bring *Alvin* and her pilot/mechanics with them. Oceanauts will become astronauts. Even as we plan to send more robot scouts to the ice worlds (NASA's Galileo mission arrives at Jupiter in 1995), oceanography and astronomy are becoming intimately and unexpectedly connected.

We are at the beginning of a fantastic adventure. We can even imagine a Europa expedition sending dolphin astronauts out to scout around the ship with their sonar, to locate drifting and/or swimming objects in the sunless sea and bring them back for study.

Today we look out upon a Solar System that seems to be filled with ice worlds. All one needs to produce oceans—and perhaps life—is internal heating of the kind seen at Europa and Enceladus. Perhaps we don't need to look for copies of Earth—worlds of just the right mass located at the right distance from just the right kind of star—to find other beings. *(If intelligent beings exist in these underground oceans, will they eventually discover space? How do you build civilizations without fire and electricity?)*

Saturn may do just as nicely for seeking life, or Neptune. We need only look someplace cold. And we need to understand that our Earth is probably in the galactic minority, if not downright freakish: a rocky world with its oceans outside. □

Charles Pellegrino is a writer and a scientist at Brookhaven National Laboratory, where he coordinates brainstorming sessions on possibilities for the next 70 years in space. His books include Darwin's Universe *and* Chariots for Apollo: The Untold Story Behind the Race to the Moon.



326 DAYS IN SPACE

Last year, Yuri Romanenko traveled 130 million miles and set a new space endurance record. What did you do?

BY LES DORR, JR.

One fine day in 1978, aboard the Soviet Union's Salyut 6 space station in Earth orbit, Yuri Romanenko's notorious temper finally got the best of him. And he exploded.

"Our argument approached the danger point. We were already raising our voices," cosmonaut Georgi Grechko recalled in an interview with the newspaper *Sovietskaya Rossiya*. "Then I felt a hand on my shoulder. Yuri was standing there smiling: 'Zhora, what are we so wound up about? The flight is going well. If we argue, we'll mess everything up...' "

Knowing when to shut up seems to be an important qualification for spending long periods in space, along with physical stamina and a great satisfaction in seeing a mission accomplished. But Yuri Romanenko surely had some special reserves to draw upon during his record-setting 326-day stay in the spartan confines of the Mir space station last year.

Consider Romanenko's feat: during ten-plus months aboard Mir, he traveled more than 130 million miles, walked in space three times, coped with an unexpected switch in crewmates, directed hundreds of medical and scientific experiments and broke two world records for space endurance. And, by one estimate, his heart beat over 30 million times in weightlessness during the flight.

On a chilly night in early February 1987, Romanenko's space odyssey began—like so many others—at the Baikonur launch center in Kazakhstan...

February 6 *(Day 0)* "The crew is ready for launch," reports spacecraft commander Romanenko, and a routine ride into orbit aboard the Soyuz TM-2 transport follows for the veteran spacefarer and rookie Alexander Laveikin. During their first day in space, the cosmonauts twice fire up the main engine of their Soyuz to steer themselves toward a rendezvous with the waiting Mir space station.

February 11 *(Day 5)* Romanenko and Laveikin complete the initial de-mothballing of Mir's systems, most of which have been dormant for more than six months. They also continue to unpack provisions and equipment sent up aboard the Progress 27 space freighter in mid-January.

February 28 *(Day 22)* Romanenko enthusiastically conducts a ten-minute tour of Mir's cozy accommodations for Soviet TV viewers. The station commander describes the mission plans and experiments, and mentions that he and Laveikin are "awaiting impatiently" the specialized scientific module scheduled to link up with Mir later in the flight.

March 13 *(Day 35)* The cosmonauts begin their sixth week in space with tests to

ALL PHOTOS: SOVFOTO/TASS

produce semiconductor materials in weightlessness. The biomedical folks on the ground also are happy: Romanenko and Laveikin appear to be in fine health after a battery of onboard cardiovascular tests.

April 5 *(Day 58)* The "Kvant" astrophysics module—an add-on to the existing Mir station—arrives, but hardly in the way the cosmonauts or mission planners had expected. As Romanenko watches helplessly, the unmanned Kvant's braking rockets fail to fire during the rendezvous operations. The 20-ton craft sails past Mir, missing a collision with the station by a scant 30 feet. While flight controllers track Kvant's orbit and analyze what went wrong, the crew settles down for an uneasy rest period.

April 9 *(Day 62)* Romanenko begins to wonder if his flight is jinxed. The Kvant module executes a textbook rendezvous with Mir, gently snuggles into the orbiting laboratory's aft docking port— and stops just inches short of a firm mechanical linkup. Baffled by this latest mishap, experts at the Flight Control Center in Moscow confer with the Mir crewmen throughout the day on possible courses of action.

April 12 *(Day 65)* On the 26th anniversary of Yuri Gagarin's pioneering spaceflight, Romanenko and Laveikin add to Soviet cosmonautical lore as they salvage the Mir-Kvant mission with an improvised spacewalk of nearly four hours.

The cosmonauts cautiously traverse the 60 feet between Mir's multiple docking adapter and the Kvant module at the station's stern. Working gingerly between the two massive spacecraft, they discover and remove the source of the problem: a small cloth bag that had jammed Kvant's docking unit. The Flight Control Center recycles the docking probe, and cheers go up when a tight coupling between the spaceships is confirmed.

May 1 *(Day 84)* Romanenko celebrates the May Day holiday with a well-deserved day off. He and Laveikin converse with their families and watch the customary festivities in Red Square.

May 15 *(Day 98)* A routine day in space for the Mir crew. They perform scheduled maintenance on the station's systems, continue to unload and activate the Kvant module, and conduct Earth surveys over Soviet territory.

May 29 *(Day 112)* A full schedule of biomedical experiments highlights Romanenko's day. The tests are aimed at calculating the oxygen content of human tissues under zero-g conditions and measuring the efficiency of the visual system after prolonged exposure to weightlessness. ▷

During ten-plus months aboard Mir, Romanenko walked in space three times, coped with an unexpected switch in crewmates, directed hundreds of medical and scientific experiments and broke two world records for space endurance.

Top: A recovery team surrounds the Soyuz spacecraft in which Romanenko and his crewmates landed on December 29. To minimize the effects of gravity after eleven months of weightlessness, ground crews carried Romanenko to a waiting helicopter. He was later able to stand up and walk around briefly on the plane ride back to the launch site. Above: Romanenko and Laveikin assemble an electrical power unit onboard Mir.

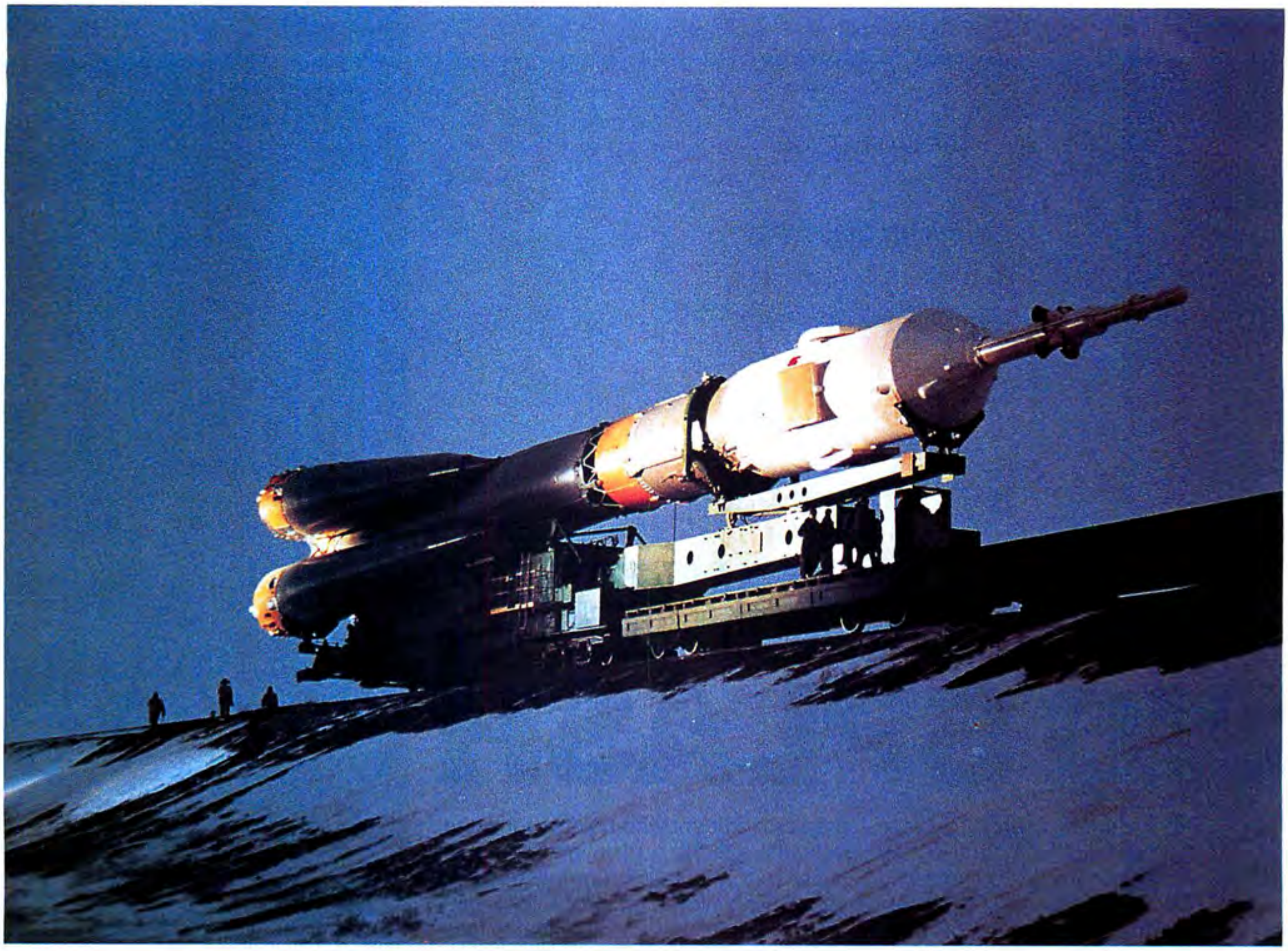
June 12 *(Day 126)* "We're getting to work," reports Romanenko as he and Laveikin take the first of two planned spacewalks to attach a third solar array to Mir's outside. For almost two hours, the cosmonauts labor to raise an extendable framework atop the station and affix the first two sections of solar cells that will provide more electrical power for their orbiting home.

June 16 *(Day 130)* Romanenko and Laveikin wrap up construction of the new 34-foot-high solar panel during three hours of extravehicular activity. The additional electricity generated by the array allows the crew to increase their experiment load, which has been curtailed due to a shortage of available power.

Shortly after the cosmonauts' spacewalk, flight surgeons become concerned about Laveikin's health. During a routine cardiovascular stress test, his EKG registers a slight irregularity in cardiac rhythm. While the condition is hardly life-threatening, the doctors question Laveikin's ability to complete the full mission planned for him and Romanenko.

When the arrythmia shows up again in a subsequent test, Soviet space officials make a difficult decision: Laveikin will be replaced by cosmonaut Alexander Alexandrov, who is assigned to the crew of the joint Soviet-Syrian mission scheduled to join up with Mir on July 24.

As station commander, Romanenko makes it known that he is not happy with the doctors' orders. During the months of pre-flight training and their stay aboard Mir, he and Laveikin have developed a close personal and professional relationship; Romanenko fears that the switch in flight engineers will prove disruptive, even though Alexandrov is an experienced cosmonaut.



Next stop, Mir: Romanenko (left, bottom) and Laveikin pose for a farewell photo before liftoff. (Above) Their Soyuz TM-2 and booster on the way to the launch pad.

Nevertheless, Romanenko listens to, and reluctantly understands, the doctors' reasoning. Ever the consummate professional, he avoids a confrontation with flight directors over the crew exchange.

July 1 *(Day 145)* Romanenko and Laveikin use the Kvant module's "Glasar" telescope for the first time. The instrument is designed to examine ultraviolet emissions in galaxies and quasars—the celestial targets from which it takes its name.

July 3 *(Day 147)* More medical tests for the Mir crewmen as they enter their 21st week in orbit. The Soviet news agency TASS reports that station commander Romanenko's pulse rate is 66 beats per minute; flight engineer Laveikin's is a slower 55.

July 15 *(Day 159)* Romanenko directs spaceborne observations of Polish terrain, as the cosmonauts participate in "Tele-Geo-87", an annual program coordinating air and space geophysical surveys of socialist countries belonging to Inter-

continued on page 62

A "Classic" Cosmonaut's Career

Even in the space-happy U.S.S.R., "Yura" Romanenko wasn't quite a household name until his marathon flight aboard Mir made him the world's most traveled spaceman last year.

Romanenko was just 26 when he joined the cosmonaut corps in 1970. Three years later, he was assigned to the backup crew for the Soviet half of the Apollo-Soyuz joint flight, and served as a capsule communicator at the Soviet Flight Control Center during the mission in July 1975.

Romanenko's first spaceflight, a 96-day sojourn aboard the Salyut 6 space station in December 1977, was billed by the Soviets as the flight of the "Classics": the "Greek," Georgi Grechko, and the "Roman," Romanenko. Their assignment was to examine Salyut's forward docking port for possible damage from Soyuz 25's failed linkup in October.

According to a story popularized by Soviet space watcher James Oberg, Grechko was to make the crucial spacewalk alone, but rookie cosmonaut Romanenko's curiosity was just too strong. Romanenko floated out of Salyut's hatch, enjoying the cosmic view from outside—until he realized that his tether was unattached, and he was about to become an unintentional human satellite.

At the last moment, Grechko supposedly grabbed the end of Romanenko's tether and pulled the shaken cosmonaut to safety. Both men, recounts Oberg in his book *Red Star in Orbit*, agreed not to reveal the incident until after their return to Earth.

The incident, if true, did no apparent harm to Romanenko's status in the cosmonaut corps. He returned to Salyut 6 in September 1980 as commander of Soyuz 38, staying in space for a week with Cuban cosmonaut Arnaldo Tamayo-Mendez.

Basking in the spotlight from his record setting flight onboard Mir, Romanenko will undoubtedly enjoy the position of the Soviet Union's most famous cosmonaut. At least until November 12 of this year. On that day Mir's current crew, Vladimir Titov and Musa Manarov, will begin their 327th day in orbit.

If a radical new

theory holds water,

the stuff in your

drinking glass may

have been delivered

from space.

BY PATRICK HUYGHE

LITTLE COMETS BIG SPLASH

Louis Frank avoids wearing his name tag at conferences, but the ploy generally fails. Everyone knows who he is. A few recognize him as the first-rate physicist from the University of Iowa. Others realize that this 50-year-old man with the boyish face is one of the top space scientists in the country. But just about everyone knows it's Frank who has proposed perhaps the most outrageous scenario of modern science—that the Earth is being showered by some twenty, 100-ton comets each and every minute of every day.

Two years ago he was just about the only one around who believed such a fantastic idea. But gradually the disbelief, anger and ridicule of his colleagues in the geophysical community have largely given way to open-minded examination and, in some cases, acknowledgement that he may indeed be correct. Being a maverick with a radical theory is one thing. Having the evidence to support it is another. Frank now has that evidence.

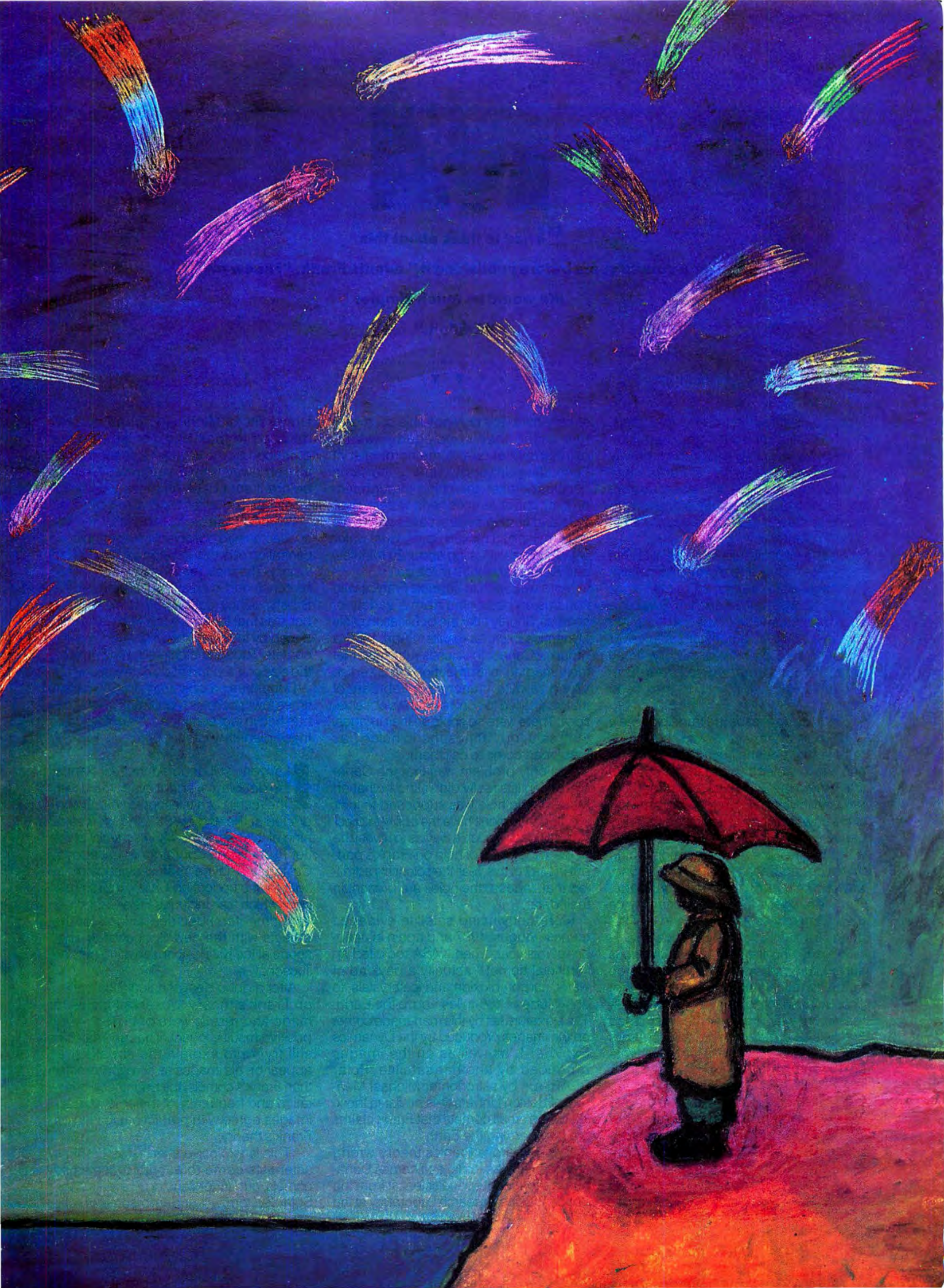
It all began in 1981, when one of the imaging instruments on the Dynamics Explorer 1, a high-altitude, polar-orbiting satellite, began relaying some puzzling data. An onboard photometer designed and operated by John Craven, a colleague of Frank's at the University of Iowa, was measuring the ultraviolet emissions from atomic oxygen in the Earth's atmosphere and producing the first global maps of the Earth's aurora. Unexpectedly, the images were speckled with dark spots.

At first, Frank and John Sigwarth, a graduate student who helped verify the data, thought the spots might be due to faulty instrumentation. Four years later, after having eliminated all possibility of a spurious effect, the scientists had to face the fact that the spots represented a genuine natural phenomenon. The next question was: What were they? Frank examined the spots, calculated their apparent size, duration and location, and concluded that they were being caused by water vapor in the outer fringes of the atmosphere. The only problem was that there isn't supposed to be any water vapor way out there.

Frank then realized that the only way you could get water vapor that high up was if it came from space, and the only known object that could deliver water vapor in such quantities was something made of ice and dust—in other words, a comet.

"I had to think about this for a couple years before publishing it," admits Frank. "I knew my life would be much simpler if I didn't. But that's not the thing you are supposed to do in science. I had to go ahead. I'm a very conservative person, and that made it that much more difficult. Now when I go get a drink of water I have to think about it in terms of water from comets."

The comets that produced the spots on Frank's images are not the comets familiar to astronomers. For one thing, they are much smaller, measured in meters rather than kilometers as in the case of Halley's Comet. On the other hand, they are much



"I had to think about this for a couple years before publishing it," admits Frank. "I knew my life would be much simpler if I didn't."

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more numerous than the known comets. Frank is talking about some 10 million comets a year being ruptured by gravity about 1,000 miles above the Earth, vaporized by sunlight, and finally sent streaming into the upper reaches of the atmosphere as clouds of water vapor some 30 miles in diameter.

That's a lot of comets, but it's not all that much water. Over a year's time it's indistinguishable from the annual rainfall—just one ten-thousandth of an inch of water a year on the surface of the Earth. If you assume, however, a constant influx over the Earth's 4.5 billion year history, these small comets would have brought in enough water over time to fill the ocean basins.

This is by no means the traditional view of the origin of the oceans. Most geologists believe that oceans first appeared long ago, when water trapped in the material that formed the Earth was "outgassed," or released in volcanic events. More recently, some scientists have suggested that perhaps comets did provide the Earth with water, but they are referring to something that occurred when the Earth was young, between 4.5 and 3.8 billion years ago. Frank is suggesting that the oceans were filled more or less gradually, and that the barrage actually continues to this day.

To many who first heard this outrageous suggestion, a few mysterious spots on some satellite images were just not enough on which to hang a radically different view of the Earth, and they dismissed Frank as being just plain crazy. "But," says Frank, "no one was able to find an alternative explanation."

A few confident souls have tried to prove Frank's theory wrong, but what they've found has astonished them. Last year, West German scientists using rockets with infrared spectrometers aboard reported finding unexpected increases of water vapor in the upper atmosphere. The only possible source for this water, they concluded, was an extraterrestrial one. A meteorologist at Penn State University came to the same conclusion after searching through records of upper atmospheric water vapor data and finding several cases where his radiometer had picked up unusual water vapor increases lasting about 20 minutes, and located about 50 miles up.

More evidence to support Frank's wild conclusion has come from a variety of sources. Shortly after the publication of his Dynamics Explorer results in April 1986, a group of Canadian scientists claimed that their imaging instrument on the Swedish Viking satellite, launched in February of that year, failed to confirm Frank's observations. There were no spots on their images, they said, no "atmospheric holes," as Frank had come to call them.

The only problem was that the Canadian scientists really didn't know what an atmospheric hole was supposed to look like, and they didn't have the ability to process their data in such a way as to reveal the holes. It took a bit of help on Frank's part, but in May of this year the scientists admitted that, indeed, the holes are present in their data.

More convincing satellite evidence came in August 1987 and again in January of this year, when NASA rocketed an "artificial comet," actually a payload of water, carbon dioxide and ice crystals, to an altitude of 186 miles above the Earth. The signature left by this man-made comet on the images produced by the Dynamics Explorer I, as well as on the images produced by another satellite, Polar BEAR, run by astronomer Michael Mendillo of Boston University, is similar to those left by the small comets that Frank claims are bombarding the Earth.

Trying to prove Frank's theory wrong has been no easy task, as Thomas Donahue, a prominent space scientist from the Space Physics Research Laboratory at the University of Michigan, found out. He decided to look back on some data produced by the Voyager 2 spacecraft as it sped away from Earth in 1977—long before it sent back all those wonderful close-ups of Jupiter, Saturn and Uranus.

What Donahue found was that the spacecraft had observed a surprising concentration of hydrogen atoms in the Earth's vicinity. The most reasonable explanation, he concluded in an article published in the British science journal *Nature* last December, was that the hydrogen was being produced by the evaporation of water from icy comets. Though he differed with Frank on the size of the population of these objects —Donahue's proposal calls for 100 million times fewer comets than Frank's— Donahue had in fact confirmed the existence of these planetary interlopers.

If anyone still doubted their existence, the doubts just about evaporated with the results of a telescopic search conducted at the end of 1987 and the beginning of this year by a NASA scientist at the Jet Propulsion Laboratory in Pasadena, California. Clayne Yeates, science manager for the upcoming Galileo Jupiter mission (which also includes Frank among its experimenters) decided to look for the objects with the new Spacewatch Telescope at the Kitt Peak observatory outside Tucson.

After a good deal of calculation based on Frank's theory, observations were made and results were obtained—very positive results, in fact. Though Yeates is still trying to explain the streaks that appear on his images as something other than Frank's comets, the brightness, orientation and frequency of the objects in his images agree with predictions based on Frank's theory.

"This is explosive stuff," says Frank. If scientists come to accept these small comets, our understanding of events in the Solar System will undergo some drastic

revisions. This swarm of comets may be responsible for traces of water seen in the atmospheres of Venus and Mars, as well as for many of the smaller craters on the Moon, the dark streaks seen in Saturn's rings and the ice found in the outer planets and their moons. Frank believes these small comets may also be responsible for the observed splitting and flaring of larger comets in the inner Solar System.

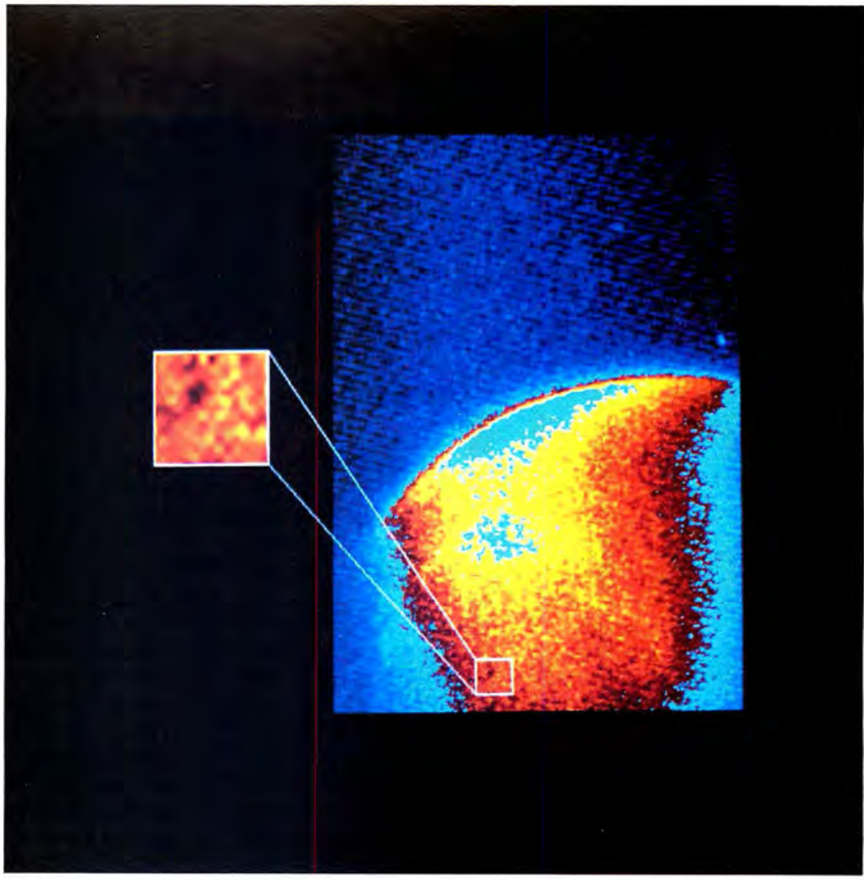
But it's their probable impact on the Earth that remains most significant. Yes, small comets may be responsible for the oceans. But they may also help explain a broad range of odd meteorological phenomena reported over the years, such things as "aerial icebergs" or "shafts of water" falling from a blue sky, odd halos, strange rainbows, unusually dark days and circular holes—several miles in diameter—that appear in otherwise dense uniform cloud decks.

A sudden influx of these comets might also help explain the ice ages, even the death of the dinosaurs. And because they act like a piston of gas when they enter the atmosphere, the invaders may even have supplied the Earth's initial inventory of life-producing organic matter.

While such speculations remain controversial at the moment, the existence of a swarm of small comets bombarding the Earth seems confirmed—for now. "It was just a thrill to see those streaks [in Yeates' images]," says Frank. This has been not only a tremendous personal victory for the theory's originator, but an immense weight off his shoulders. Many of his other projects have had to take a backseat over the past two years.

"Now," Frank says, "I can get on with my life." But removing his name tag still probably won't do any good. □

Patrick Huyghe is a freelance science writer in Westchester County, New York. He has written for magazines, educational television and National Public Radio.



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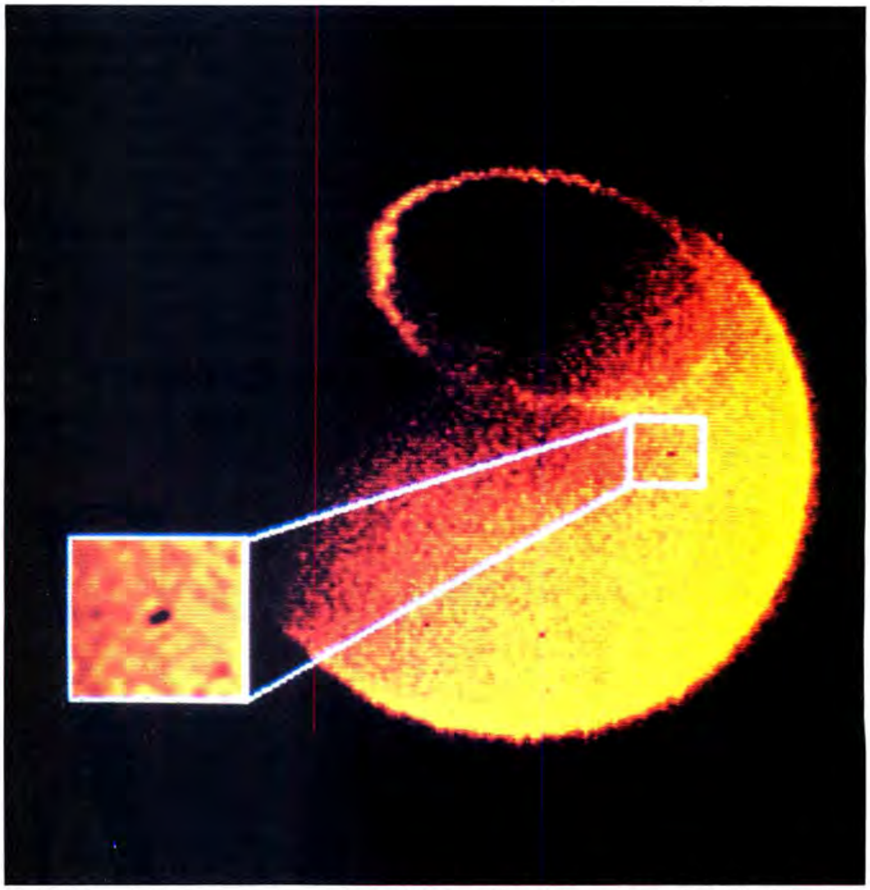

The Evidence: Dark atmospheric "holes" (below, inset) first appeared in ultraviolet images taken of the Earth by the orbiting Dynamics Explorer spacecraft. More recently, the holes also appeared in images of the northern hemisphere taken by the Swedish Viking satellite (top).

A DISCOVERY IN JAZZ

Composer Jane Ira Bloom will try to capture the emotion of the next shuttle launch with her spacey saxophone sound.

BY C.J. SOUTHENS

Space fascinates Jane Ira Bloom—not only the stuff out there with a capital "S" to be colonized and conquered, but small "s" space as well. The space in "spatial relationships," the 3-D medium of sight and sound.

A New York-based jazz composer and performer, Bloom is the first musician ever invited to participate in NASA's 25 year-old documentary art program. Three days before Discovery lifts off on the next shuttle mission, Bloom will rendezvous in Florida with a team of five other artists—three painters, an illustrator and a collage maker. As NASA's guests, the team will get an intense behind-the-scenes view of the countdown and launch, sketching, photographing and—in Bloom's case—audio taping their impressions.

Then they'll return to their studios to create works based on the experience, to record whatever it is that camera and video cannot capture, but art can. That was what legendary NASA administrator James E. Webb had in mind when he created the art program in the early 1960s and recruited artists like Jamie Wyeth, Robert Rauschenberg and Norman Rockwell to apply their "unique insight to...our history-making advance into space". If anyone can offer unique musical insight, it's Bloom. One of the few female jazz composers in a male-dominated field, she plays an infamously difficult instrument to master—the soprano saxophone. It's a woodwind, or reed instrument, that looks more like a large, silvery clarinet than the familiar curvy alto or tenor sax. Played ineptly—and sometimes even by the best —it has a rude tendency to squeal off-pitch. Few jazz artists other than Bloom play it exclusively. It's rarely written into orchestral scores, and it doesn't have a role in *Peter and the Wolf.*

Nevertheless, Bloom gets raves. At 33, she already is a six-time winner of Downbeat's Jazz Critics Poll for soprano sax, and has been recording on small labels and performing at major festivals in Europe and the States for over a decade. In 1987, she signed with CBS records. *Modern Drama,* her first album for the giant company, appeared last fall.

Much of her music has a *quark*y spirit to it. The main themes are set in advance, but the final result is always improvised. Bloom, in fact, prefers to call herself an improvisor rather than a jazz musician. Both in recording and in performance, she uses live electronic effects, spontaneously swelling and modifying the sound of the saxophone with a tap on the foot pedals of a digital delay and harmonizer. The delay stretches the tone, allowing it to crescendo and then fade. The harmonizer overlays delicate intervals on a single note, creating the intricate chords of Gregorian chant or

DEAN CHAMBERLAIN

the music of the spheres.

In tunes like "Overstars" and "Miro", individual notes hurtle meteor-like from one ear to the other, dragging trails of sustained sound behind them. It's an effect the animators of Fantasia would have loved. Listen. You can picture blazes of rainbow-tinged light streaking across an indigo sky. One zooms in from the left. *Whoooooosh.* And one from the right. *Shoooooopah.*

Watch Bloom closely in performance and you begin to see how she does it. She is a small woman, barely five feet tall. When she raises the saxophone to her lips, it comes all the way down to her knees. Her dark blond hair is cut chin length and pushed off her face with a hint of spikiness. She's wearing a midnight blue doublet-and-hose sort of outfit—a short flared jacket and slightly rumpled thick tights—and black, old-fashioned looking lace-up shoes. Pinned to her left shoulder is a gold abstract brooch hammered into a bolt of lightning. She describes the getup as futuristic, and it's not hard to imagine Joan Jetson in it. You can also see Peter Pan or Puck from *Midsummer Night's Dream,* because when Bloom plays, light flashes off the saxophone, sound careens around the stage and there is definitely magic in the air.

Magic. And movement. Bloom's music is not toe-tapping fare by a long shot. There's no *kachung-kachung* backbeat to make heads jive and fingers snap. Instead, by her own dancing moves, Bloom shows us the subtle rhythms that she hears. She takes exaggerated, fluid, spacewalking steps that give the appearance that gravity has gone awry on the stage. Or she slashes the horn through the air, swinging it high over her right shoulder like a baseball bat, describing a rapid arc to her left shoulder, blowing a note that sounds just like the parabola of light blazing off the sax looks. Sometimes she throws herself off balance. Or she lunges forward into the horn as if warming up to run, then leans precariously backward and stays there, cantilevered from the knees. You don't just listen to Bloom make music, you watch her. And in fact, motion is an integral part of the music she makes.

She explains. "There are many parameters to music: pitch, rhythm, melody, harmony and traditional timbres. But one parameter that we often don't think about—and that a lot of contemporary composers have occasionally mused about—is how music can change when it moves. Music can become a different thing when it's not just stationary, when it moves, or when it surrounds your ear, perhaps."

Offstage, dressed in a plain brown sweater and slacks, sitting crosslegged in a hotel room chair, Bloom loses her elfin, sprite-in-Space quality. She has a surprisingly forceful voice and her conversation is cerebral, cautiously censored of jazz lingo for an interview with a space writer. She is obviously well-educated—B.A. and M.A. in music from Yale—but not at all didactic. "I got a sense of fairy dust sprinkled around," blurts the reporter in describing the performance. "Really?" Bloom laughs easily. "Whatever impression works for you. Fine. That's okay."

It's that relaxed live-and-let-live attitude that makes her such an accomplished improvisor and collaborator. (She usually performs and records with a three- or four-piece band: piano, bass, drums and sometimes vibes.) But it is her intellect and interest in spatial relationships and motion that set her apart from so many other jazz musicians. It's not easy to swing the horn around like a golf club and, well, swing. Most players stand stolidly in front of the mike out of necessity.

When she performs, Bloom takes exaggerated, fluid, spacewalking steps that give the appearance that gravity has gone awry on the stage.

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"In some forms of improvising, that motionless stance is because a great deal of thought is going into note choice," Bloom says. "You can't be moving around a lot when you're trying to execute very difficult harmonic and melodic patterns. Your brain can only handle so much information, and I've been sort of pushing mine to do some things that perhaps it's not used to doing—moving and playing at the same time."

Bloom has also been exploring the use of innovative playing environments and sound systems to deliver the goods in something other than a straight line. "When you go to a concert someone stands on a stage, plants their feet, faces you, projects a sound and it comes at your ears. It's a very unidirectional experience. I'd like to be in a space in which I could execute some of my ideas about surrounding the senses with sound. And usually that takes more of a circular arrangement."

For the New Music America festival, she performed her composition "Doppler's Revenge" from second base of the Houston Astrodome. The audience in the stands heard the music through a circular speaker system. In New York a couple of years ago, she did a concert with circular miking. "The musicians revolved in kind of a satellite system of microphones. Then I had the sound going through a set of speakers that surrounded the audience so that they would get the spatial sense—even though this was an Earthbound concert—of what it was like to have music swirl and surround their ears from all directions, to orbit their seats. People were fascinated. It was definitely an exciting experience. But I'm just doing little experiments touching on the things that excite me or make me curious. Maybe a planetarium would get closer to the idea," she muses.

Or maybe it would work in space. "Perhaps music would be different in zero gravity," she says, "if music was communicated between people no longer as a one-to-one, direct stationary correspondence."

Bloom's steady, matter-of-fact voice rises with excitement. "I'm sure in a future time, composers may think about predicting or directing your attention to how music may come at your ear. Not just here," she says bringing her hands up to the sides of her head like earphones, "but from here." She looks up to the right and waves a hand over her head. "And from here," she gestures to the left. "And from up and down."

Her curiosity about music in zero-g prompted Bloom in 1985 to write the NASA public service office in Houston for information on the arts in space. Houston directed her to Bob Schulman, the head of the NASA Art Program in Washington. Schulman, himself a painter, was as fascinated by Bloom as Bloom was by space.

In her letter she mentioned that her performances often had her spinning and playing sax at the same time, and wondered if NASA's interest in studying gymnasts' sense of balance might extend to musicians. "Her letter was provocative," Schulman understates. At first, there was a possibility that the third private citizen chosen to fly on the shuttle—after a schoolteacher and a journalist—would be an artist, musician or poet. But Christa McAuliffe's death onboard Challenger ended all that.

Instead, Schulman offered Bloom "the next best thing"—a spot on the Discovery art team. She will pay her travel expenses to the Cape and to the desert landing site at Edwards Air Force Base in California. NASA will pay her—and each team member—a $2,000 honorarium for her planned work: a suite of jazz compositions covering the complete cycle of the mission, from launch to landing. What the music will sound like, and exactly how it will be used, are still, appropriately, up in the air.

"I do certainly have some ideas," says Bloom, "but I would like to leave my ear open and spontaneously react to the

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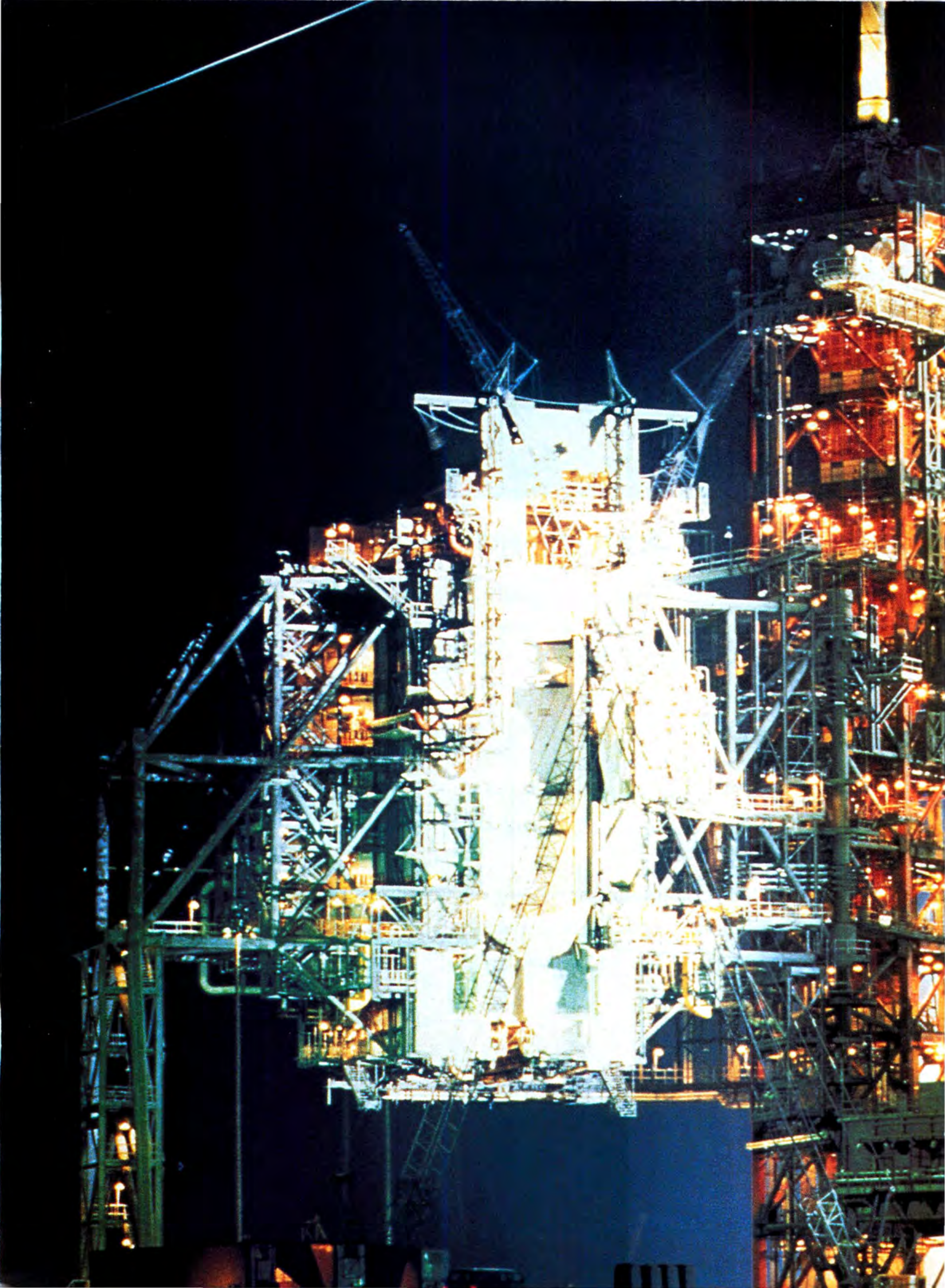

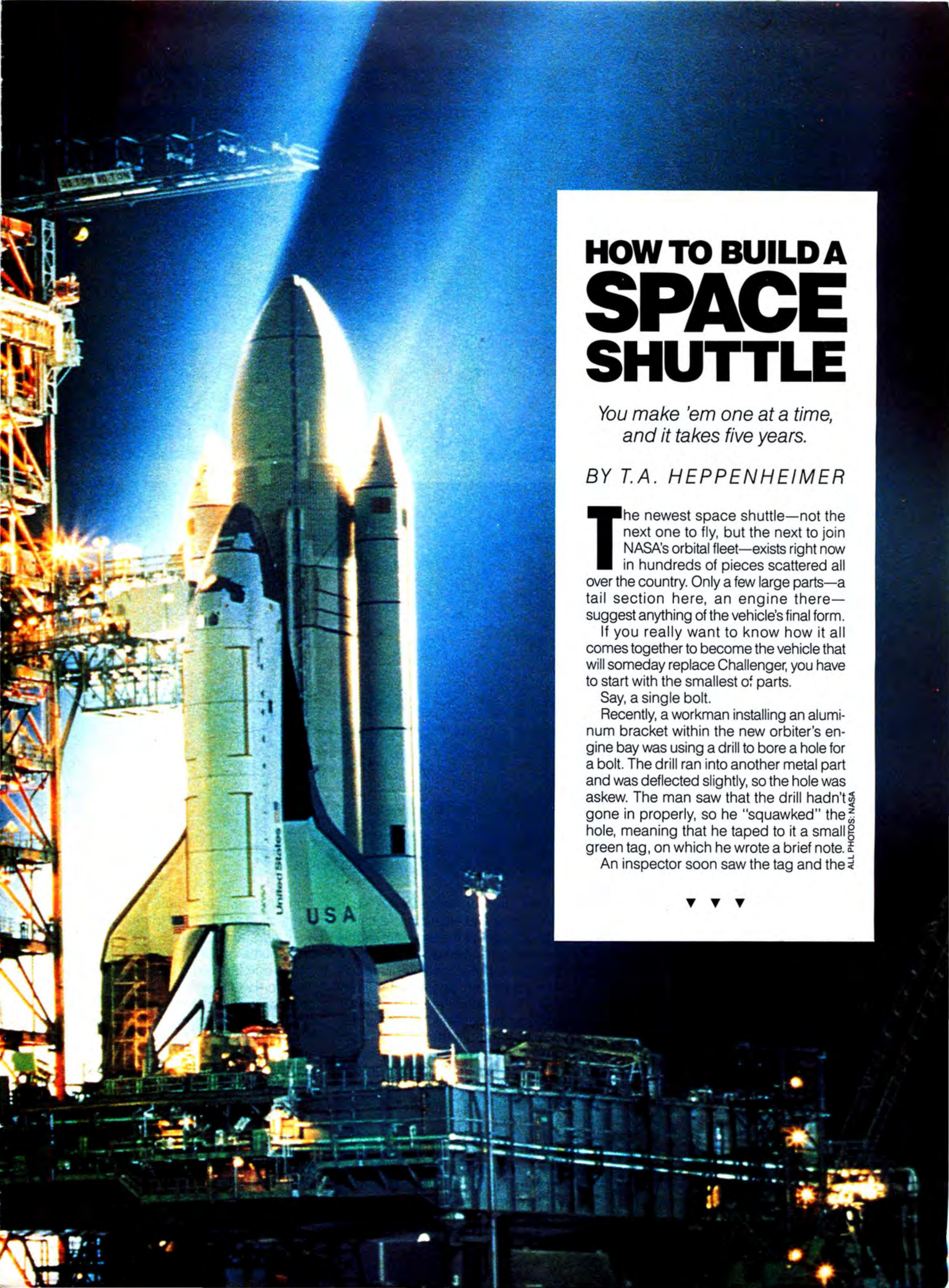

HOW TO BUILD A SPACE SHUTTLE

You make 'em one at a time, and it takes five years.

BY T.A. HEPPENHEIMER

The newest space shuttle—not the next one to fly, but the next to join NASA's orbital fleet—exists right now in hundreds of pieces scattered all over the country. Only a few large parts—a tail section here, an engine there—suggest anything of the vehicle's final form.

If you really want to know how it all comes together to become the vehicle that will someday replace Challenger, you have to start with the smallest of parts.

Say, a single bolt.

Recently, a workman installing an aluminum bracket within the new orbiter's engine bay was using a drill to bore a hole for a bolt. The drill ran into another metal part and was deflected slightly, so the hole was askew. The man saw that the drill hadn't gone in properly, so he "squawked" the hole, meaning that he taped to it a small green tag, on which he wrote a brief note.

An inspector soon saw the tag and the

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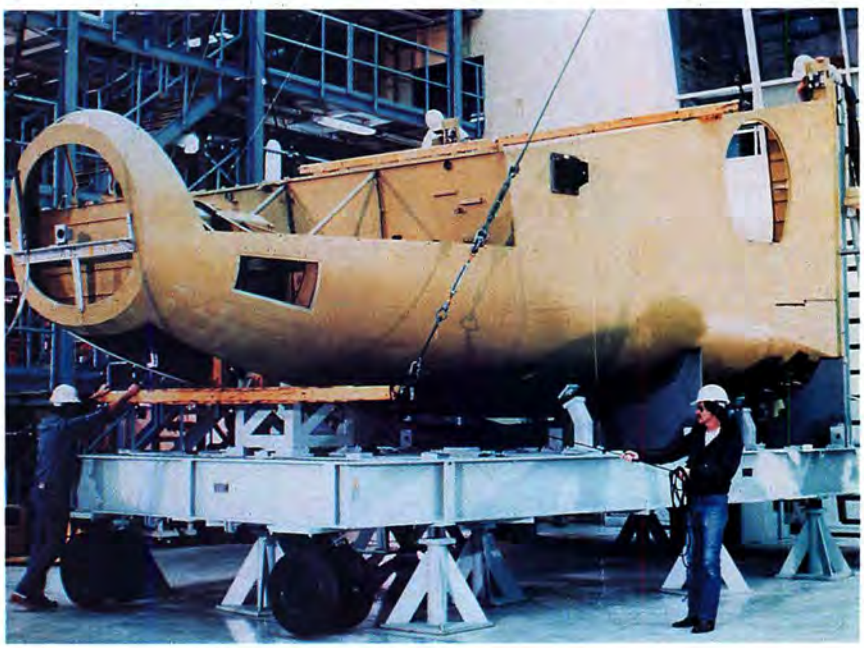

They build the orbiter slowly, painstakingly, in the fashion of the craftsmen of old who built the great clipper ships.

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faulty hole, and checked the detailed engineering specifications for how the hole should have been drilled. He then proceeded to measure it with care, noting how it deviated from the specs. Then he filled out a form known as an MRD, or Material Review Disposition.

That was only the beginning.

The MRD went over to the engineering staff, where, among hundreds of engineers, there was one individual who had responsibility for that bracket and its bolts. He got out his working drawings, with their detailed depictions of what the hole should properly be, and proposed a solution: Re-drill the hole, using a slightly larger shank, and use a bigger bolt. The new hole, in turn, would be large enough to wipe out the error.

His proposed solution then went over to a different technical department, Stress Analysis, where other engineers made calculations. Would the larger bolt and hole cause any new problems? After a couple of days, they decided the solution was acceptable, and sent back their approval.

Soon the workman had his instructions: Change the drill shank, re-bore the hole, slip in the new bolt. Meanwhile, a company vice-president had been following all this closely, to make sure that any problem wouldn't spread further.

All this trouble for something akin to hanging shelves in your den and finding that you've pounded in one of the nails at a slight angle. But that's what it's like, assembling the new orbiter. The work is an elaborately choreographed exercise in meticulous care and attention to detail.

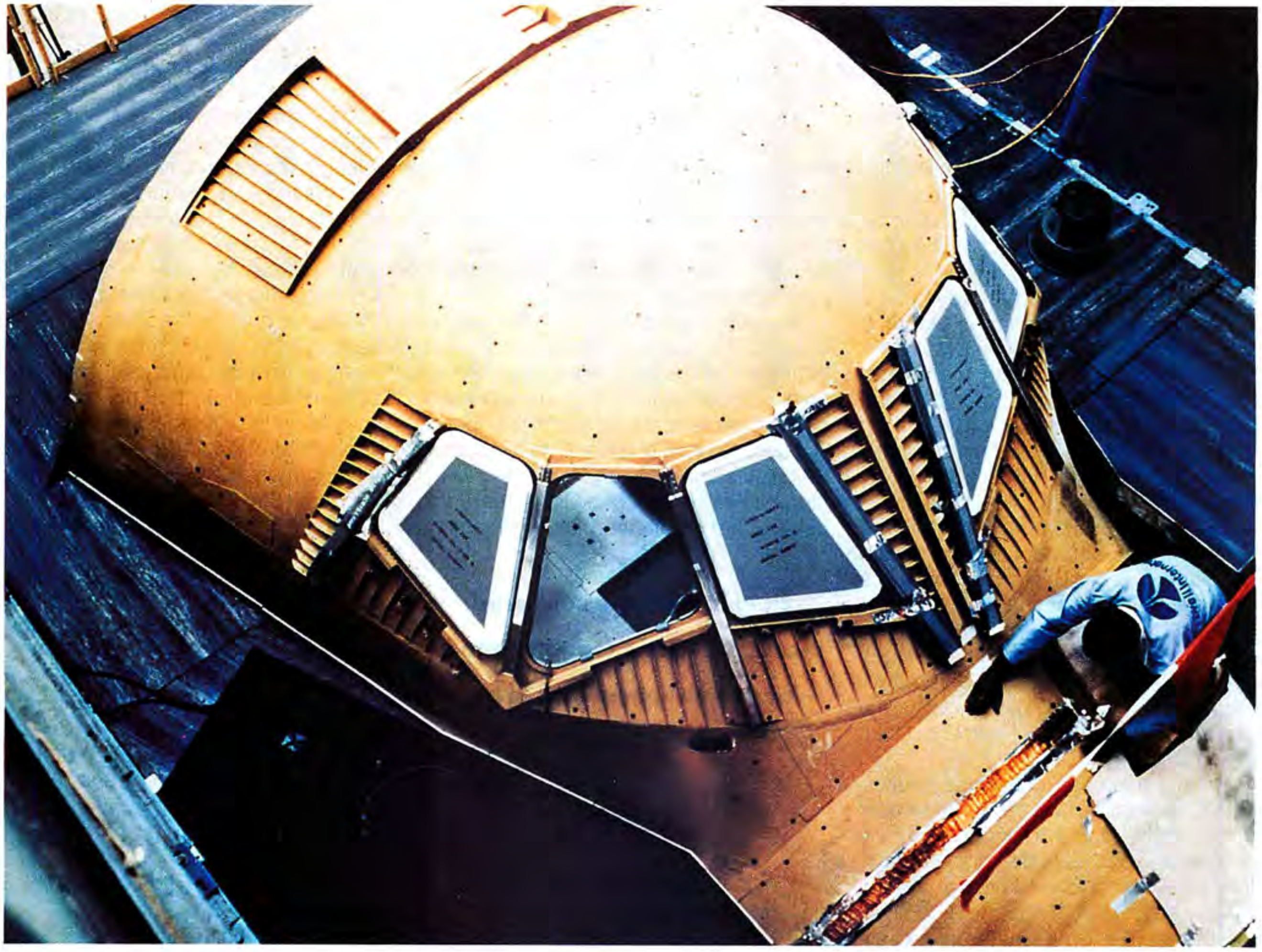
The people doing the work are highly experienced artisans, adept not only at using their tools but at reading blueprints —a skill that sets them apart from ordinary workmen. They build the orbiter slowly, painstakingly, in the fashion of the craftsmen of old who built the great clipper ships. Most aircraft mechanics work on a production line, where they learn through repetitive experience. But like the clippers of the last century, the new orbiter is one of only a very few.

Certainly it would have saved money if all the shuttles could have been built as production aircraft, but that's not the way the program has gone. "We have had big gaps in the production sequence," says Don Whitman, vice-president for orbiter production at Rockwell International, the main contractor for assembling NASA's next shuttle vehicle.

"We built Enterprise (a prototype orbiter used for landing tests) and Columbia together. Then we had a two-and-a-half to three-year lag. Most of the people went off the program; we had to bring them back and retrain them. We also had long gaps between Challenger and Discovery, and prior to the next one, Atlantis.

"You try to get the same people back; sometimes you can't. New people then have to read the drawings. This isn't like building a line of DC-10s at McDonnell Douglas. We build 'em one at a time, and it takes five years."

Despite the fact that many of the workers



have no prior space shuttle experience, they aren't working in the dark.

As Whitman recalls, "When we finished Atlantis, the last vehicle before people were laid off or transferred, we had the workers, supervisors and managers write down lessons learned. We asked, 'If you were going to build another vehicle, what would you do differently?' Some people put down, 'I would fire my boss.' But we also got advice such as, 'I would install certain brackets and braces *before,* not after, I would install the wiring.'"

On the new orbiter, the workers have the benefit of this earlier experience. They also have videotapes that show directly what their counterparts did at ticklish moments in building the earlier craft.

And always, there are plenty of inspectors. "You'd be looking at the quality of workmanship, checking the location of the installed part," adds Whitman. "If it's installed with fasteners, you look at the size of the fastener, the number of threads that are showing. The spec might call for, say, three and a half to five threads. If more are showing, the guy has used the wrong bolt, so you'd 'squawk' that." This stringent quality control ensures that any mistakes will be caught at the earliest stages.

Right now, the new orbiter is designated

The new orbiter comes together at the Rockwell facilities in Palmdale and Downey, California: Attaching a wing (opposite page, top); the lower forward fuselage section (bottom); checking out the cockpit-like crew compartment (above).

only as OV-105, Orbiter Vehicle 105. Its sister ships have similar numbers: Columbia is OV-102, Discovery is 103 and Atlantis, 104. Number 105 has no name, however. To honor Christa McAuliffe, the teacher who died aboard Challenger, NASA officials have decided that a name for the new orbiter will be picked from suggestions to be submitted by the nation's schoolchildren.

Major parts of number 105 are already several years old, dating back to 1983. At that time, NASA and the White House were caught up in an argument about whether to build a fifth orbiter vehicle to supplement the busy shuttle fleet. NASA's leaders wanted it badly, but budget-cutters in the Reagan administration were against it.

Gilbert Rye, an Air Force lieutenant colonel on the staff of the National Security Council, proposed a compromise; Rather than funding a complete orbiter, NASA should proceed with building "structural spares," major sections of the craft to be held in reserve. The spares would include new wings and a tail, as well as major portions of the fuselage. The idea was that if one of the existing vehicles were to be badly damaged in a landing, it wouldn't be totalled, but could be rebuilt. And if NASA ever truly needed a new orbiter, the spares would provide a head start for its assembly.

With the structural spares as a starting point, construction of the new orbiter has been underway since August 1987. To see what's involved in the assembly, you start by entering Building 1 of Rockwell's plant in Downey, California, only a few blocks from the nation's oldest operating McDonald's stand. Like the McDonald's, this plant is a golden oldie, dating to World War II. It has a sawtooth-style roof more fitting for a factory in the Rust Belt than for a high-tech business. Its floor is of concrete, swept clean of dust and litter, smooth from decades of use.

The floor spans several acres, big enough for a substantial production line of fighter aircraft or bombers. But there is only one item under construction within this vastness: the aft portion of the fuselage for OV-105, where the cluster of three main engines will go. This rear part of the

fuselage is a barnshaped structure, about twenty feet high, with three immense cutout holes in it where—much later—the rocket motors will be mounted.

The aft section is made of green aluminum, covering a framework of aluminum beams. It stands alone in the middle of the floor. Nearby is an engineer's desk spread with working drawings. Someone has left his glasses there, next to a roll of scotch tape.

Two long steel platforms are in place within this section for the workers to stand on. Today they are installing brackets—sheet-metal supports for the maze of ducts, tubes, cables, pressure vessels and other components that will follow.

The orbiter's main liquid-fueled engines are nowhere in sight. They are being built at another Rockwell division, Rocketdyne, in nearby Canoga Park. At Rocketdyne, a continuing development effort is underway, aimed at giving the engines more thrust. This will increase their ability to withstand their greatest moment of stress, a bit over a minute into the shuttle flight, when the pilot receives the command, "You are go for throttle-up." At that time, the engines blast away at 104 percent of their rated power.

In the words of a Rocketdyne spokesman, "You wouldn't want to run your auto engine right up to the margins, and we don't want to on the shuttle engines either." Indeed, Rocketdyne in time will test the OV-105 engines at 109 percent, to show that they have enough performance margin. These engines will match the ones already installed on Discovery, the next orbiter scheduled for launch.

It will be years, though, before the engines are fitted into place within the empty shell that now stands amid the sprawling enclosure of Building 1. Other portions of OV-105 are in a similar enclosure next door, across a parking lot. Walk in a side door; here is another brightly-lit bay with a concrete floor, four stories high. Close by is the upper forward fuselage, which covers the top of the crew compartment. It looks like a very large and sleek automobile. A long hood extends to the front, with a rakishly swept-back windshield sporting six windows. Its roof, in turn, merges smoothly into the rear, without a back window. It is too big to be street-legal, however, measuring more than 15 feet across.

You can stand at the back of this section, looking forward, and get what is nearly an astronaut's-eye view through the windshield. But this, too, is merely a shell of green aluminum, its outer surface festooned with a number of "squawk tags," the green paper tags that note minor faults. Here is a freshly drilled hole that must be cleaned of metal cuttings stuck to its interior. Close by is the seam between two adjacent panels of sheet metal; they are to be sanded flush where they meet. These things will be done within a day or two.

Farther up the floor is the crew cabin, built as a two-story compartment with the cockpit on the top level. Again, it's little more than a shell right now, a chassis-like array of beams and sheet metal with brackets attached. Down below, on the lower level, is what someday will be the mid-deck where astronauts will sleep, prepare food and use the toilet.

You stand behind it and look through a large square opening with gray walls, the future site of the airlock separating the crew quarters from the cargo bay that opens out into space. Through the opening, amid temporary fluorescent lights, is a roof painted off-white and festooned with more stalactite-like brackets. It's easy to believe that the final orbiter will feature 37,000 such mounting braces, each installed with meticulous care.

In Palmdale, the scattered pieces will come together into a complete spacecraft, to be ready by April 1991.

▼ ▼ ▼

At the front of this mid-deck is a double set of newly-installed shelves, which will hold the computers and other electronics. The space shuttle is notorious for having computers whose basic design dates to 1971, meaning that they are less powerful than the desktop systems sold at your local computer shop.

The most recent versions of the shuttle's computers, which are already installed on Discovery and Atlantis, do offer some improvement, however. Similar models will be installed in OV-105. The new computers perform one million operations per second and have 262,144 32-bit words of memory, a two-and-a-half-fold increase in both speed and memory over the old versions. The new ones are also more compact, filling a single unit whereas their predecessors required two. Like the other orbiters, OV-105 will carry five computers.

Leaving the mid-deck, you descend some steps and continue on to the lower forward fuselage. It looks like a modest-sized boat, even though it's fifteen feet wide; something like the royal barges of the Pharaohs. It has a definite prow, with a boxy and cabin-like structure halfway down its length, which will enclose the crew compartment. There also is a side hatch for the astronauts, and a bay for the nose landing gear, which is large enough to hold a piano.

Not far away is another major structure, which will fit in place atop the bows of the "boat." Within its interior, mounted to the framework, are a number of large cylindrical and silvery forms that look like lampshades. These look like the light bulb holders that support your car's tail lights inside the trunk, only much larger. They will hold the small rocket engines that will point in all possible directions to steer the orbiter in space.

It is a powerful and arresting sight: Much of the shell of a complete shuttle orbiter is here. Other major sections— principally the wings and tail, and the remaining fuselage—are a hundred miles away in Palmdale, where the final assembly will take place. Many more smaller pieces are still being manufactured by subcontractors located throughout the country.

The sight of an orbiter in pieces brings to mind the recovered fragments of the lost Challenger, which were salvaged from the sea and laid out on a similar concrete floor, in a recent, more melancholy time. Now, however, the pieces tell of hope.

"Come August or September, we start receiving hardware form the vendors," declares Whitman, the Rockwell vice-president. "Tanks, actuators, valves, relays, fuel cells." Work crews will install each in turn, weaving these components into a whole, along with the pipes and cabling, ducts and controls.

"We just keep doing that until we finish the aft fuselage in September 1989. Then we send it up to Palmdale. The crew module goes up in November or earlier, though I may decide to ship it up in June or July of 1989." In Palmdale, the scattered pieces will finally come together into a complete spacecraft, to be ready by April 1991.

According to the schedule, OV-105 then will be hoisted on top of a Boeing 747 used for transporting shuttle orbiters, to be ferried across the country to the Kennedy Space Center. It will trundle into the mammoth Vehicle Assembly Building, the gargantuan cube that towers over the Florida palmetto as one of the world's largest enclosed buildings.

There the new orbiter will have its main engines installed, and will undergo another nine months of pre-flight preparation. Finally, in March or April of 1992, according to current plans, it will be ready for its first flight into space. Amid the thunder of rockets, as flocks of birds are startled into flight across the green landscape, this new addition to the nation's spacefaring fleet will rise on its pillar of dense, white smoke.

And the lost Challenger, finally, will be redeemed. □

T.A. Heppenheimer is a science writer in southern California. His most recent book is The National Aerospace Plane *(Pasha Publications, 1987).*

DATA BASE

Space Shuttle Missions 1981-1986

FLIGHT	VEHICLE	CREW	LAUNCH	LANDING	MISSION HIGHLIGHTS
STS-1	Columbia	**Commander:** John W. Young, **Pilot:** Robert A. Crippen.	April 12 1981	April 14 1981	First launch of the Space Transportation System (STS) and first landing from space.
STS-2	Columbia	**Commander:** Joseph H. Engle, **Pilot:** Richard H. Truly.	November 12 1981	November 14 1981	First test of shuttle's robot arm. First Earth remote sensing experiments.
STS-3	Columbia	**Commander:** Jack R. Lousma, **Pilot:** Charles G. Fullerton.	March 22 1982	March 30 1982	First student experiment flown. First and only landing at White Sands, New Mexico.
STS-4	Columbia	**Commander:** Thomas K. Mattingly, **Pilot:** Henry W. Hartsfield.	June 24 1982	July 4 1982	Final test flight of the Space Transportation System. First commercial experiment.
STS-5	Columbia	**Commander:** Vance Brand, **Pilot:** Robert F. Overmyer. **Mission Specialists:** Dr. Joseph P. Allen, Dr. William B. Lenoir.	November 11 1982	November 16 1982	First operational mission. First four-man crew.
STS-6	Challenger	**Commander:** Paul J. Weitz, **Pilot:** Karol J. Bobko. **Mission Specialists:** Donald H. Petersen. Dr. Story Musgrave.	April 4 1983	April 9 1983	First flight of Challenger. First "spacewalk" from the shuttle. (Petersen and Musgrave).
STS-7	Challenger	**Commander:** Robert L. Crippen, **Pilot:** Frederick C. Hauck. **Mission Specialists:** John M. Fabian, Dr. Sally K. Ride, Dr. Norman Thagard.	June 18 1983	June 24 1983	First American woman in space (Ride). First five person crew.
STS-8	Challenger	**Commander:** Richard H. Truly, **Pilot:** Daniel C. Brandenstein. **Mission Specialists:** Dale A. Gardner, Guion S. Bluford, Jr., Dr. William Thornton.	August 30 1983	September 5 1983	First night launch and landing. First flight of an American black in space (Buford).
STS-9	Columbia	**Commander:** John W. Young, **Pilot:** Brewster H. Shaw. **Mission Specialists:** Owen Garriott, Dr. Robert A. Parker, Dr. Byron K. Lichtenburg, Dr. Ulf Merbold.	November 28 1983	December 8 1983	First foreigner to fly on the shuttle (Merbold). First Spacelab mission.
41-B	Challenger	**Commander:** Vance D. Brand, **Pilot:** Robert L. Gibson. **Mission Specialists:** Bruce McCandless II, Robert E. McNair, Robert L. Stewart.	February 3 1984	February 11 1984	First untethered "space walks." First landing at Kennedy Space Center in Florida.
41-C	Challenger	**Commander:** Robert L. Crippen, **Pilot:** Francis R. Scobee. **Mission Specialists:** Dr. George D. Nelson, Dr. James D. Van Hoften, Terry J. Hart.	April 6 1984	April 13 1984	First in-orbit capture, repair, and redeployment of a free-flying spacecraft.
41-D	Discovery	**Commander:** Henry W. Hartsfield, **Pilot:** Michael L. Coats. **Mission Specialists:** Judith A. Resnick, Richard M. Mullane, Steven A. Hawley, Charles D. Walker.	August 30 1984	September 5 1984	First flight of Discovery. First deployment of three satellites on one mission.
41-G	Challenger	**Commander:** Robert L. Crippen, **Pilot:** Jon A. McBride. **Mission Specialists:** David C. Leestma, Sally K. Ride, Kathryn D. Sullivan, Paul Scully-Power, Marc Garneau.	October 5 1984	October 13 1984	Kathy Sullivan becomes first American woman to walk in space. First Canadian in space (Garneau).

DATA BASE

Space Shuttle Missions 1981-1986

continued

FLIGHT	VEHICLE	CREW	LAUNCH	LANDING	MISSION HIGHLIGHTS
51-A	Discovery	**Commander:** Frederick H. Hauck, **Pilot:** David M. Walker. **Mission Specialists:** Anna L. Fisher, Dale A. Gardner, Joseph P. Allen.	November 8 1984	November 16 1984	First flight to discharge two satellites and retrieve two other satellites.
51-C	Discovery	**Commander:** Thomas K. Mattingly, **Pilot:** Loren J. Shriver. **Mission Specialists:** James f. Buchli, Ellison S. Onizuka, Gary Payton.	January 24 1985	January 27 1985	First mission dedicated totally to Department of Defense.
51-D	Discovery	**Commander:** Karol J. Bobko, **Pilot:** Donald E. Williams. **Mission Specialists:** M. Rhea Seddon, S. David Griggs, Jeffrey A. Hoffman, Charles D. Walker, Sen. E.J. "Jake" Garn.	April 12 1985	April 19 1985	Jake Garn becomes the first senator (politician) to fly in space.
51-B	Challenger	**Commander:** Robert F. Overmyer, **Pilot:** Frederick D. Gregory. **Mission Specialists:** Don L. Lind, Norman E. Thagard, William E. Thornton, Lodewijk van den Berg, Taylor G. Wang.	April 29 1985	May 6 1985	First operational flight for Spacelab. First time monkeys flown on the shuttle.
51-G	Discovery	**Commander:** Daniel Brandenstein, **Pilot:** John Creighton. **Mission Specialists:** Shannon Lucid, Stephen R. Nagle, John Fabian, Patrick Baudry, Sultan Al-Saud.	June 17 1985	June 24 1985	Three communication satellites deployed. First Saudi Arabian to fly in space (Al-Saud).
51-F	Challenger	**Commander:** Charles G. Fullerton, **Pilot:** Roy D. Bridges. **Mission Specialists:** F. Story Musgrave, Anthony W. England, Karl G. Henize, Loren W. Acton, John-David Bartoe.	July 29 1985	August 6 1985	First Abort to Orbit when one engine shut down early.
51-I	Discovery	**Commander:** Joe H. Engle, **Pilot:** Richard O. Covey. **Mission Specialists:** James Van Hoften, John M. Lounge, William F. Fisher	August 27 1985	September 3 1985	Fisher and Van Hoften perform longest shuttle "spacewalk" yet, lasting seven hours and one minute.
51-J	Atlantis	**Commander:** Karol Bobko, **Pilot:** Ronald J. Grabe. **Mission Specialists:** Robert Stewart, David Hilmers, William A. Pailes.	October 3 1985	October 7 1985	First flight of Atlantis. Second mission dedicated to Department of Defense.
61-A	Challenger	**Commander:** Henry W. Hartsfield, **Pilot:** Steven R. Nagle. **Mission Specialists:** James F. Buchli, Guion S. Bluford, Jr., Bonnie J. Dunbar, Reinhard Furrer, Ernst Messerschmid, Wubbo Ockels.	October 30 1985	November 6 1985	First eight-person crew. First German Spacelab mission.
61-B	Atlantis	**Commander:** Brewster H. Shaw, **Pilot:** Bryan D. O'Conner. **Mission Specialists:** Mary L. Cleave, Sherwood C. Spring, Jerry L. Ross, Rodolfo Neri Vela, Charles Walker.	November 26 1985	December 3 1985	First Mexican national in space (Vela). First space "construction" experiments.
61-C	Columbia	**Commander:** Robert L. Gibson, **Pilot:** Charles F. Bolden Jr. **Mission Specialists:** Franklin Chang-Diaz, Steven A. Hawley, George D. Nelson, Robert J. Cenker, Cong. Bill Nelson.	January 12 1986	January 18 1986	First congressman in space (Bill Nelson).
51-L	Challenger	**Commander:** Francis R. Scobee, **Pilot:** Michael J. Smith. **Mission Specialists:** Judith A. Resnick, Ellison Onizuka, Ronald A. McNair, Christa McAuliffe, Gregory Jarvis.	January 28 1986	—	First launch failure of the shuttle program, 73 seconds after liftoff, claimed the vehicle and the lives of the crew.

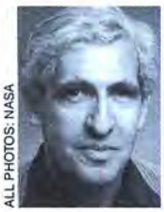
Adrift ON THE *Winds* OF *Mars*

BY GREG FREIHERR

Ballooning across alien planets, laying "eggs"—it all came to Jacques Blamont—how else?—in a dream.

They will float silently in the Martian night, tens of millions of miles from their home: Two balloons—one filled with hydrogen, the other deflated, dangling listlessly above the planet's pock-marked surface. Inside a 10-meter guide rope tethered to the balloons, lying flat on the alien landscape, will be chemical analyzers, busily churning out data. At dawn a distant Sun will heat the balloons, and they will rise into the pink morning sky for another day of traveling wherever the wind blows them.

They will be the first lighter-than-air spacecraft ever to visit Mars. Scheduled for lift-off in 1994 atop a Proton rocket, the balloons will mark a scientific and diplomatic triumph for the French who built them and the Soviets who launch them. They also will be tangible proof that Jacques Blamont, the mastermind of planetary ballooning, has been right all along. "I have often said it is difficult to walk on Mars, but it is easy to fly," he quips.



ALL PHOTOS: NASA

Mars will be the second alien planet for which Blamont, a leading scientist with the French space agency Centre National d'Etudes Spatiales (CNES), has designed balloons. Venus was the first. It was on a night back in 1967, he remembers, that the idea came to him in a dream.

"I could see a balloon in the Venus atmosphere," says Blamont. "At the time I didn't care about balloons and I didn't care about Venus."

But the next morning he wrote a letter to the Soviet Academy of Science on precisely those two subjects, which initiated joint studies between the French and Soviets that continued through the 1970s. Meanwhile, Blamont was promoting his ideas in the West, using balloons to take data in the Earth's atmosphere and send them to orbiting relay satellites.

Then, in 1980, Roald Z. Sagdeev, director of the Soviet Space Research Institute in Moscow, formally proposed that two Soviet missions to Venus include balloons. Blamont, who had been serving as a consultant with the Jet Propulsion Laboratory in Pasadena, California, got the Americans involved. Five years later, two balloons launched by a Soviet rocket and tracked by American antennas were floating in the clouds of Venus, taking data on atmospheric composition and winds.

So successful was the VEGA balloon flight that Blamont's ideas for similar missions in the skies of Mars were put on the drawing boards of both American and Soviet space agencies. With relations between the two superpowers at their best since the mid-1970s, leaders from both governments have talked openly in recent months about cooperating on Martian exploration missions.

But, says Blamont, "There is a very large distance between words and deeds. That is what is so very hard."

Blamont has worked with JPL scientists for nearly two decades to develop the concept of space ballooning. He has otherworldly ideas that extend beyond Mars to the edge of the great gas planets. "Titan (a moon of Saturn) would be ideal for the balloons," Blamont says. "But the Cassini mission (a proposed NASA project to study Saturn) doesn't care about balloons.

MIKE CARROLL

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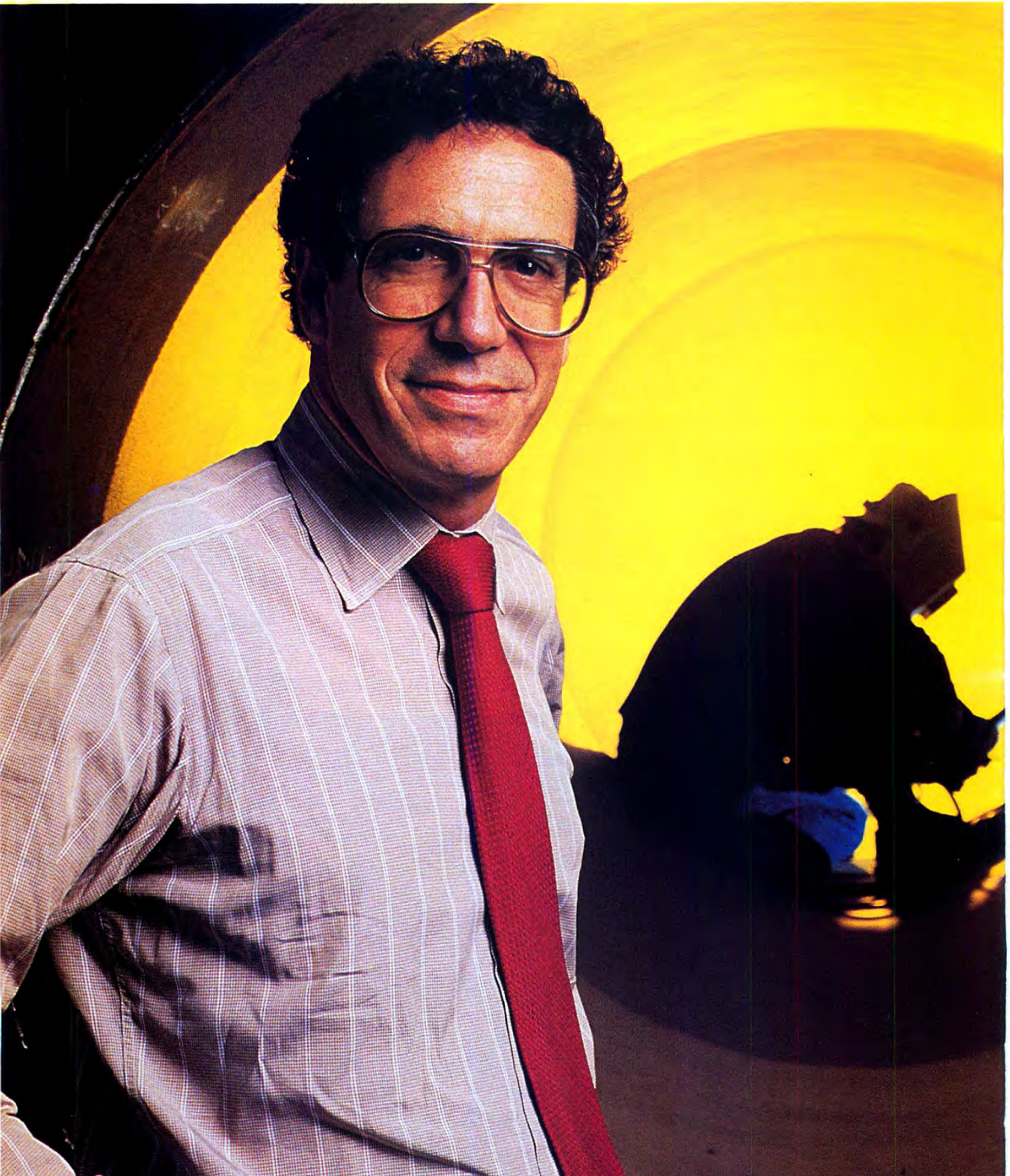


George Koopman: careening between possibility and disaster.

ED KASHI

Starting an independent rocket company is not for the faint of heart, nor the short of cash.

BY MELINDA GIPSON

the RISE *and* FALL *and* RISE *of AMROC*

George Koopman lives life at the edge. Before he started his own rocket company, he achieved some measure of fame as the man who coordinated the racing, crashing and smashing of a score of police cars on Chicago's Lower Wacker Drive at the end of the Belushi/Aykroyd film *The Blues Brothers.* Now, as he navigates a maze of rocket tests, suppliers, government procurement contracts and skeptical financiers, he's still careening between possibility and disaster.

The pitfalls of the maze have brought Koopman's American Rocket Company (AMROC) to the brink of extinction more than once. Yet the company survives,

occupying both a factory in downtown Camarillo, California and a rocket test stand at nearby Edwards Air Force Base. AMROC still needs millions of dollars to complete its rocket development program. But Koopman has no intention of quitting.

The vision that keeps him going is that of a low-cost launch vehicle, which Koopman hopes will become a kind of space delivery truck in the next decade. According to an early company release, "AMROC has sacrificed the race car performance of current expendable launch vehicles, all based on military missiles, for the cost-efficiency of a delivery van."

Koopman conceived of this vehicle and founded AMROC with $50,000 of his own money in May 1985. He set out to design a launcher with three times the performance of other rockets in its class, at less than one-tenth the cost of a government-sponsored program.

The market for such a flying delivery van seemed to exist even in those days before the Challenger accident. Koopman reasoned that a low-cost, mass-produced "industrial" rocket vehicle might inspire development of a new class of satellites. Small, serviceable communications or reconnaissance satellites and government- and university-sponsored experiments, assured of an inexpensive lift, would multiply like rabbits.

Unlike the "race cars" based on military missiles, Koopman's vehicle would be kept simple. "When the government designs a rocket," he said, "it has to be able to respond instantly to the president's call on the red phone, fly out of the atmosphere in 90 seconds, halfway around the world, in time of war, through hostile countermeasures, with no external source of guidance, and deliver its payload to one of 10 different Soviet missile silos with a high degree of accuracy. That costs a good deal more than the rocket we're building."

To put it in more practical terms, "If Federal Express tried to deliver its packages with F-16 fighter planes, they'd be out of business overnight."

AMROC's first venture was to be an industrial launch vehicle able to carry 4,000 pounds to low Earth orbit, at a cost of $5 million to $8 million per launch. As late as May 1987, the goal was to launch a suborbital test flight in December 1987, followed by the first orbital flight in December 1988.

That would be no small feat, considering that AMROC was offering a whole new class of launch vehicle, using technology that hadn't been exploited for 20 years. For his engine, Koopman chose a hybrid—a rocket that combines solid fuel with a liquid oxidizer that allows thrust to be varied and the engine to be turned on and off. By contrast, most expendable rockets—Titans, Deltas, Atlas-Centaurs—use liquid fuel. The shuttle's booster rockets are entirely solid. The trick to mixing the two technologies is to evenly channel the liquid oxidizer after it is squirted into the rocket chamber.

One advantage to keeping fuel separate from oxidizer until ignition is that the rocket won't explode in handling. That way, Koopman reasoned, the expensive "marching army" of safety personnel required in government launch programs would be unnecessary. Another advantage is that the rocket can be switched on and off. It can be fired five separate times in a single 70-second burn, allowing engineers a look after each interval, which would lower testing time by one-fifth.

"I have a stack of three-by-five cards that I live with day and night —each one with a prospective investor on it—and I play solitaire with them every day. Some people I know are capable of writing me a check for a million bucks."

But as AMROC engineers tested and explored, they had to lower their expectations of how much their initial vehicle could lift. The original design was changed to include another whole tier of rockets, which added weight. What had served as a source of pride in the company's early announcements—the number of times the engines had been tested—became an embarrassment as the testing dragged on and on.

But the tests also attracted the attention of the Air Force, which was providing the company with its test facilities. And they caught the eye of AMROC's first customer: the Pentagon's Strategic Defense Initiative (SDI) organization.

The people charged with making President Reagan's Star Wars system a reality might seem an unlikely buyer, given Koopman's aversion for established military procedures. But AMROC's potential to accomplish a flight plan quickly, outside the usual Defense Department establishment, appealed to SDI maverick Lt. Col. Mike Rendine.

So convinced was Rendine that no other rocket company could perform as quickly and cheaply as AMROC, that in early October of last year he negotiated contracts with the company as the "sole source" for launch of two 220-pound test payloads.

Then, just as Koopman seemed on top of the world, he collided head-on with catastrophe. What happened was Black Monday. In the wake of the October 19 stock market crash, the wealth of several monied individuals who had promised funding for AMROC vanished overnight. The company had to lay off everyone but Koopman and a partner, and was unable to pay suppliers for the delivery of its initial flight hardware. Reluctantly, Koopman had to tell the SDI people that he doubted AMROC could live up its bargain.

The troubles didn't let up. Chief Financial Officer William Claybaugh cleaned out his desk when Koopman refused to take refuge from creditors under Chapter 11 of the Federal Bankruptcy statutes. Though many engineers stayed on and worked without pay to maintain skeleton operations, AMROC's chief engineer, Jim French also left the company. Things got even darker in December when Koopman's father Richard, who had both invested in AMROC and served on its board, died of cancer.

Then, just when the first creditors began appearing in court to demand payment, a miracle happened. One of Koopman's suppliers referred him to a private investor who had amassed a fortune as a government contractor in a non-aerospace field. This anonymous "angel," whom Koopman describes as "an extremely unlikely character" to be interested in a start-up rocket company, not only bailed the company out of its troubles, but gave it the capital to rehire two-thirds of its work force.

The eleventh-hour save didn't put an end to AMROC's money troubles, however. "We're still sailing very close to the wind," admits Koopman. Financial and corporate markets, for the most part, had closed their doors to AMROC even before the market crash. Black Monday has made it tougher than ever to raise venture capital.

Wolfgang Demisch, a noted Wall Street aerospace analyst who examined the company's prospects early on, said he lost confidence in AMROC when it reconfigured its rocket design. The doubts have been stoked further by the disparaging words of disenchanted former employees, the most credible of whom is former engineer Jim French. For 19 years French was a senior NASA engineer at the Jet Propulsion Laboratory. Before that he served as TRW's chief test stand engineer for the Apollo lunar lander.

French left AMROC not because of a financial crisis, but because of what he saw as a crisis of credibility. "Koopman appeared to me to be promising things he couldn't deliver," he said. Eventually French was "no longer willing to put my technical reputation on the line for his daydreams."

Hybrid engines might be of some use as a first stage in smaller launch vehicles, French believes. They do have a safety advantage over all-solid or all-liquid rockets. But they are four to five times as expensive to develop as liquid rockets, and they don't bring commensurate cost savings, according to French.

He praised Koopman's "extraordinary" fund raising abilities and his ability to marshal a team of "some of the best engineers in the country," and said he was very distressed at having to leave the company. But, he continued, "I've seen it before; the optimistic funding profile is still there long after the optimistic funding isn't. That's how NASA got into trouble with the shuttle."

Claybaugh talks about the company's slavery to schedule at all costs. He lambastes Koopman as "among the most abusive managers I've ever worked for. . . He'd come in with some new idea, having a deadline of three weeks ago, and get mad at you for not having been working on what he'd just figured out."

Claybaugh sees as a more important failing the company's inability to attract—or tolerate the control of—a corporate partner. Space Services Inc., AMROC's competitor in the fledgling private launch market, has the backing of a local financial group, and other space ventures have attracted support from established aerospace firms.

Ironically, the most potent threat to AMROC's existence is the legacy of its own success in interesting the Pentagon in smaller, less expensive launch vehicles. Last spring, the Defense Department's Defense Advanced Research Projects Agency (DARPA) began looking into the possibility of using small, cheap satellites for battlefield reconnaissance or to restore lost communications capabilities in the event that a nuclear war blinded other systems.

And *what* may I ask is so funny?

Although the merits of this "lightsat" concept are still being debated at the Pentagon, DARPA decided to offer as many as four $300,000 study grants to explore the idea, which could lead to even more money for whichever contractor comes up with the best design and implementation plan. A first flight is planned in July 1990, a second five months later, and one quarterly thereafter. From such seeds are billion dollar businesses born.

Winning the "lightsat" contract would be like being christened the heir to a family fortune, and private money would surely follow for the Defense Department's anointed one. As a result, many companies were expected to bid for the study contracts, toughening AMROC's competition.

But having already collected some $10 million for his project, Koopman is hardly willing to play the role of a Prometheus bringing fire to other rocket companies. He said that AMROC has submitted its own "non-traditional" proposal in the DARPA competition.

With all the forces that threaten to undo AMROC, it's hard to believe that there never has been a better time to start a rocket company. Yet the president's recent space policy, which bans NASA from maintaining its own fleet of expendable launch vehicles (even though it still allows DOD to develop rockets), encourages all government agencies to buy launch services from the private sector.

Many schemes are underway to finance commercial launch facilities with private money, which would ease the headache of negotiating launch pad use agreements with the Air Force. As more private capital is drawn to space ventures, more facilities may become available. It depends on the success of those in the vanguard.

Does all this good news come too late for AMROC? Koopman says no. With the ease that comes from having made and spent several fortunes, he contends that "AMROC lives."

"We continue to raise money from what I call venturesome capitalists. I have a stack of three-by-five cards that I live with day and night—each one with a prospective investor on it— and I play solitaire with them every day. Some people I know are capable of writing me a check for a million bucks.

"I've been told since I started this business, 'You don't know what you're doing; you'll never get anywhere.' I still continue to have absolute faith in what I'm doing." □

Melinda Gipson is an aerospace writer and editor of the biweekly Space Business News.

BOUNDARIES

The Great Lunar Helium Rush

It may be gas, not gold, that draws prospectors to the Moon.

▼ ▼ ▼

by Maura J. Mackowski

Remember when you were a little nipper, sucking up helium from party balloons and amazing your friends with an out-of-this world imitation of Donald Duck? Are you still the life of every party? What would you say if someone told you that a balloonsworth of the squeaky stuff was easily worth a half a kazillion dollars?

That's exactly what Gerald Kulcinski of the University of Wisconsin is telling the world, and people are starting to take their heads out of their balloons to listen.

An isotopic cousin of helium, He-3, is a magical substance that may, according to its proponents, become the first truly valuable extraterrestrial import — a product that is not obtainable here on Earth, is readily available in space, and is very, very, saleable. The promise of this wonder gas is nothing less than a clean, economical solution to the world's energy crisis. An ideal fuel for nuclear fusion, He-3 is extremely stable, and it produces almost none of the waste and radioactivity associated with the fission reactors that currently produce a small fraction of the world's energy.

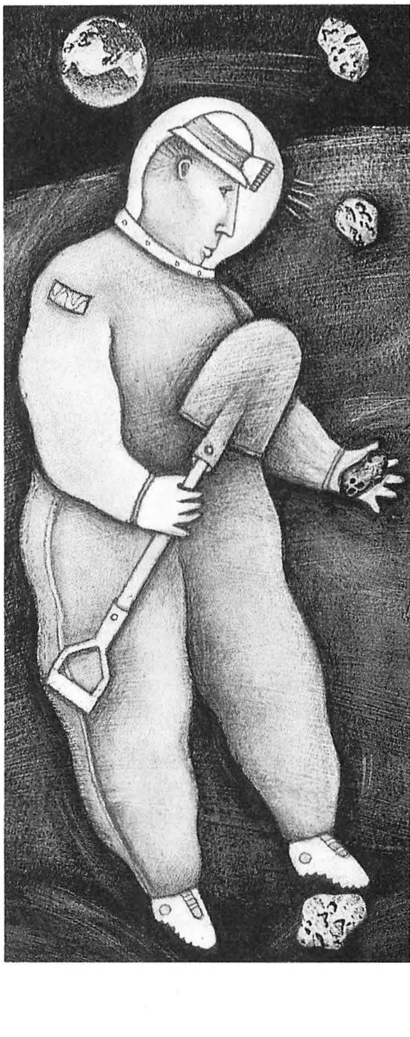
In front of every silver lining there's a cloud, however. No large-scale, completely successful fusion reactor has been built and operated, at least not yet. But several groups are working on developing the technology, and with luck and coordination, fusion reactors could be dotting the globe by the time the first space tanker arrives from the Moon.

Astronautics Corporation of America in Madison, Wisconsin, is one of the companies looking seriously at Kulcinski's idea, using NASA funds to study what kinds of autonomous mining operations would be needed to extract He-3 from lunar soil and turn a concept into an economic reality.

Ron Teeter, manager of the company's space systems department, points to the advantages of nuclear fusion over fission. "With fission reactions there's a splitting of very heavy atoms," he explains. "This produces a lot of radioactive byproducts, free neutrons and contamination. The big problem is maintaining these [reactor] sites and working around them."

"Fusion reactions fuse two very small atoms together into a larger one," Teeter continues. "Deuterium and tritium (two "heavy" isotopes of hydrogen) are the most common ones to fuse. Fusion is much more efficient; there's much more energy output and less radiation because the reaction produces fewer free neutrons. In a deuterium/He-3 reaction, theoretically there are no free neutrons at all. We're talking orders of magnitude in terms of hazard reduction."

Our Sun is the source of the He-3 known to exist in the inner Solar System. Over the last four billion years or so, solar winds have blown it toward Earth, but our atmosphere and electromagnetic field have prevented it from reaching the surface in more than microscopic quantities. Not blessed with either an atmosphere or a strong electromagnetic field, the Moon's soil has been a much better collector. Apollo astronauts brought back enough rock specimens to prove that He-3 exists on or just beneath the Moon's surface in exploitable quantities.



MARGARET HUBER

If a viable nuclear fusion industry is established on Earth, this lunar gold dust seems likely to enrich space prospectors sooner than any other proposed extraterrestrial resource. Chipping away at asteroids for base metals found in cheap abundance on Earth has yet to fire up any financier to bankroll a high-risk space endeavor. And compared with lowering a bucket into the atmospheres of Saturn or Jupiter (the Solar System's real mother lodes of helium gas), a jaunt to the Moon is short and simple. We've been there. Furthermore, we've had several millennia's success on Earth with mining.

Kulcinski predicts that developing fusion reactors to process lunar fuel will take approximately 25 years — just about the same time, he guesses, that Moon tankers would be docking in Earth orbit, their holds heavy with helium gold.

The value of the gas would be no laughing matter. Kulcinski estimates that twenty tons of He-3 would provide the U.S. with enough energy for a year, equivalent in 1987 dollars to $40 billion worth of fuel. This twenty tons could be strip-mined from a 100-square mile patch of lunar soil two meters deep. Processing the lunar soil with a simple solar heater would also generate hydrogen for rocket fuel, and plenty of water to support a lunar base.

Those who have jumped on the Helium-3 bandwagon admit that it will take some technological effort to bring our nuclear fusion capability up to snuff, and the combined efforts of various scientific and engineering disciplines will be needed before the first shovelful of lunar dirt is turned.

But given the economic and ecological potential, even Daffy Duck wouldn't say no to this one. □

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Ascent

(continued from page 21)

sure on my chest, back and stomach. I strained against them by tightening my stomach. Although I had experienced G forces in supersonic jets, there were stronger than I expected. Then I realized it was because I was on my back, and the force was sustained for almost two minutes through the chest. The sensations were much different from those I'd experienced in the backseat of an F-16 as it made tight fifteen-second turns, only momentarily ripping the oxygen mask off my face and causing my lips to pull away from my teeth.

Suddenly, over my earphones, I heard the words that made my skin prickle. "We have a malfunction."

As we reached orbital velocity, the main engines suddenly cut off. Instantly, the G forces disappeared, replaced just as suddenly by weightlessness.

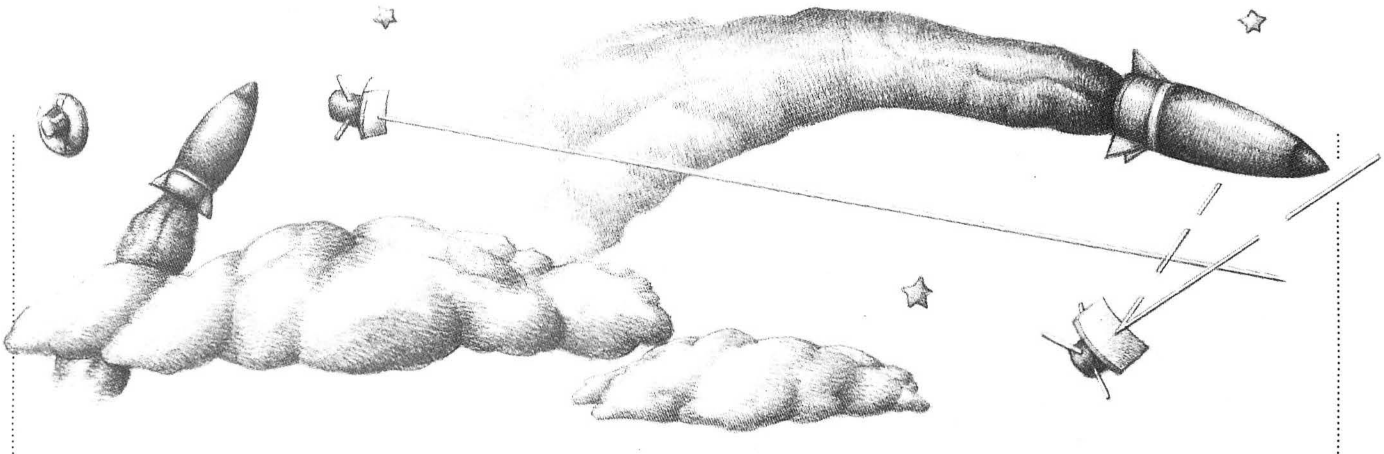
Now in zero gravity, still strapped to my seat, I stared in wonderment as my arms started floating at chest level right in front of my eyes. I glanced over at Franklin. His arms were floating, too. Debris on the cabin floor, which had shaken loose during the vibrations of the ascent, was starting to float up. The entire powerful ascent had taken only eight minutes thirty-six seconds. I felt a mixture of gratitude and disbelief.

The huge external fuel tank, now empty of its liquid hydrogen and oxygen, suddenly separated with an audible bang. It blew away and fell, tumbling back into the atmosphere where it would burn up on reentry.

Fred Gregory, our CAPCOM at Mission Control back in Houston, greeted us enthusiastically: "Welcome to space, rookies!" □

Excerpted from Mission, *by Bill Nelson with Jamie Buckingham. Copyright © 1988 by Bill Nelson and Jamie Buckingham. Published by Harcourt Brace Jovanovich, Inc.*

REVIEWS



Claiming the Heavens: The New York Times Complete Guide to the Star Wars Debate.
by Philip M. Boffey, William J. Broad, Leslie H. Gelb, Charles Mohr, and Holcomb B. Noble, TimesBooks, 299 pages, $17.95.

by Thomas O'Toole

Few issues of the late 20th century are as contentious, indecipherable and overwhelming in scale as President Reagan's Strategic Defense Initiative, known otherwise as the "Star Wars" defense against nuclear missile attack. Start with size. The SDI defense could cost between $150 billion and $1 trillion, and be grander in scope than antiquity's pyramids and the Great Wall of China together, bigger by far even than the Manhattan Project to build the atomic bomb or the Apollo Project to land men on the Moon. It might be like asking engineers to bridge the English Channel. Or architects to mount a skyscraper 300 stories high.

Move beyond size to complexity. A "Star Wars" defense system would involve scores of laser battle stations in space, dozens of orbiting "fighting mirrors" to relay the killer beams, thousands of spaceborne sensors to locate missiles before they leave the Earth and at least as many computers to sort out real missiles from the hundreds of decoys sure to accompany them in flight. No fewer than 5,000 rocket launches will be needed to get all this hardware in space — about two perfect flights a day, every day for more than 15 years.

The hardware carried into orbit will have to be almost perfect, too, since it can't be shut down for repairs in space all the time. Then there's the software to instruct the computers on how to defense an all-out nuclear attack and do it in a matter of minutes. The world has never experienced nuclear war, but SDI's software designers will have to anticipate how many missiles and decoys will be fired, the tactics they'll use and what impact those tactics will have on the defenders' sensors and computers.

Writing SDI's computer instructions has been likened to developing a computer program to process America's tax returns for the year 2020 without knowing what the 2020 tax laws will be. And don't forget, there is no way to test the SDI system beforehand, no chance for a rehearsal. The first time it is ever tested will be the only time it is ever used.

There's no question SDI has stirred up a big bouillabaisse, as chronicled in this meaty book by a team of five *New York Times* reporters, who won a 1986 Pulitzer Prize for their 1985 newspaper series on SDI.

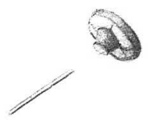
Even the Pentagon was shocked by Reagan's March 23, 1983 announcement of the plan to make nuclear weapons "impotent and obsolete." And for good reason. The Pentagon, the *Times* book tells us, didn't know the announcement was coming. "It's not a bomb, is it?" asked an incredulous Defense Secretary Weinberger.

The shock spread fast. Budget watchers were horrified at what such a program might cost: $150 billion for research alone, out to the year 2000. Arms controllers saw in the Reagan plan a belief that nuclear war could be controlled, fought and even won, a new and dangerous approach that could drive a leader to risk starting a nuclear war. There were "Star Wars" critics everywhere, who felt that it would touch off a new and more dangerous arms race than the one we'd been living with for the last 40 years.

To hear the *New York Times* tell it, there's nobody in between on "Star Wars," even today, five years after it was first pronounced. Those who've embraced it see SDI as the force that brought the Soviets to the bargaining table. "SDI is the best thing that ever happened to arms control," declared Richard Sybert, a special assistant to Weinberger. "It moved the Soviets to show flexibility in their proposals. It has prompted the first Soviet proposal for a real cut in offensive missiles." Henry Kissinger: "Strategic defense is the only new idea that points away from the excessive reliance on nuclear weapons, which threatens strategy with paralysis and arms control with triviality."

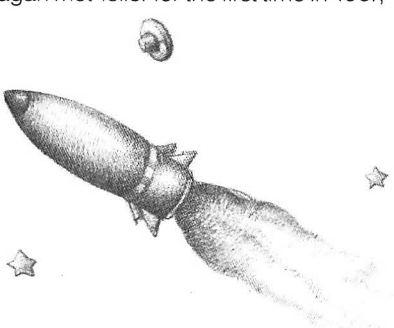
Those who hate "Star Wars" see it unglueing the "mutual assured destruction" (MAD) philosophy that has kept the peace for 40 years. After all, even a 95 percent effective defense would allow 500 warheads to hit the United States. "No responsible official could suggest that with such a system in place, nuclear war was any more acceptable than it is today," said Gerard C. Smith, chief American negotiator of the 1972 ABM Treaty. "The only way to protect our country from nuclear war is to prevent nuclear war."

That's how most Europeans see it. "The Europeans actually tend to like nuclear weapons," Colonel Jonathan Alford of London's Institute for Strategic Studies said. "They don't say we want more and



more of them, but they say it is nuclear weapons, their existence, the fear they induce, which has made it impossible to contemplate war."

According to the *Times* team, the spirit behind the "Star Wars" defense has been Edward Teller, the Hungarian-born physicist who also was the spirit behind the hydrogen bomb almost 40 years ago. Reagan met Teller for the first time in 1967,



just after he became governor of California. If Teller felt guilt about his role in the hydrogen bomb, he never expressed it. But he did express to Reagan his fear of thermonuclear war. "I have lived through two world wars," Teller said. "I don't want to live through a third."

Teller apparently is convinced that the force of nuclear explosions can be channeled into beams of radiation to act as a shield against nuclear missile attack. He also is convinced that construction of the shield in space is not an impossible feat, a conviction not shared by many of his colleagues. "Edward is a physicist with a fantastic creative mind," one of those colleagues told the *Times* team. "But his first H-bomb was the size of an apartment house. He understands the beauty of a piece of music, but for God's sake, don't ask him to design a trumpet."

The first line of defense in any "Star Wars" shield will be the gun, as it has been in all wars. The "gun" that has most excited Teller and his disciples is the x-ray laser, which can only be stimulated by nuclear explosion, has never been tested and may never be tested. What is exciting about the x-ray laser is that it is one of the few weapons on the drafting board that might destroy an enemy's missile fleet in the "boost phase," when the missiles are still rising from the Earth.

The other approach is to build a giant laser gun whose beam will be a searing ray of free electrons, not x-rays. Earthbound, this laser would need a string of relay mirrors in orbit to bounce its beams halfway around the globe to strike missiles just before or after they exit the atmosphere. It's why the biggest, most powerful laser on Earth is being built at the White Sands Missile Range on the edge of the New Mexico Desert. Cost: at least $1 billion. Purpose: to test out the killer free-electron laser.

Both laser concepts have the clear, loud ring of science fiction, and there's a very dubious Catch-22 attached to the free-electron laser: its killer beam may be ineffective if too weak, and impossible to handle if strong enough to be effective.

Lurking in all the spaceborne defense concepts is the hidden software curse, more mishandled and misunderstood than any mere puzzle of nuclear and laser physics. The Navy's new Aegis system for protecting ships at sea has a hard time tracking 150 targets with the software its computers use. Star Wars will have to handle 250,000 missile and decoy targets at once.

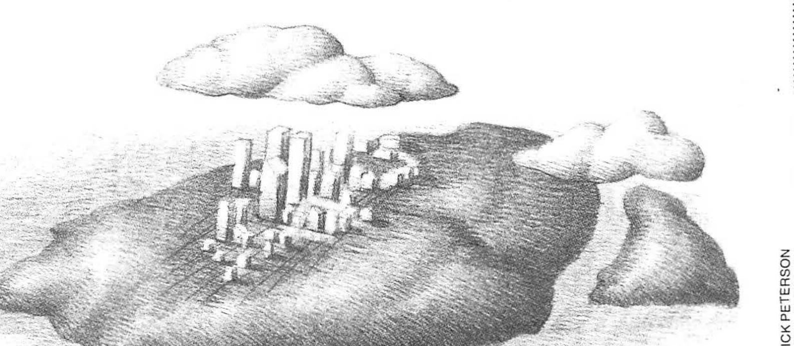
Star Wars' computer program will be the largest by far ever written, the largest ever attempted. Estimates range anywhere from 25 million to 50 million lines of code or instruction, which would make it 20 to 40 times as big as the codes for the nation's telephone network. The bigger the program, the more chance for error.

"We're talking about a system that can't afford mistakes," said Dr. Herbert Simon of Carnegie-Mellon University in Pittsburgh, the only computer scientist to win a Nobel Prize. "It scares the bejeezus out of me." Fourteen computer specialists at AT&T, whose software system for routing telephone calls around bottlenecks is the best in the nation, signed a letter to the Pentagon warning that Star Wars might have 10,000 errors in its software, any of which could cripple the system.

Despite the kisses of death the program gets from the *Times* team's book, Star Wars will be with us in some retrenched shape or form for years to come. Look over the daily headlines and what do we see? Pentagon pronouncements that the first (and possibly only) stage of the program will be a defense of the nation's missile silos. Which means defense with interceptor missiles and weapons called "smart rocks," fired either from Earth or from low-Earth orbit. No x-ray lasers. No fighting mirrors. No unsolvable software problem. No inviolate shield protecting America's people from the threat of nuclear missile attack. Maybe that's the way it should be. The only defense against nuclear massacre may indeed be the threat of nuclear massacre.

The *Times* book is a thoughtful, provocative tome that will doubtless be required reading for people wanting to know everything they can about "Star Wars." The book has its flaws, the worst of which is that it is repetitive, having been written by a gang of five. Nonetheless, it is a serious attempt to cast light on a serious subject. □

Thomas O'Toole covered the space program for The Washington Post *for 20 years, and is a past winner of the National Space Club Press Award.*



RICK PETERSON

Adrift on the Winds

(continued from page 50)

I couldn't sell it to them."

Last year, NASA funds for extraterrestrial ballooning dried up completely. Before then, JPL scientist James Burke had been closely involved in the development of a Mars balloon project.

"When Blamont first suggested this sort of thing, people might have thought he was too optimistic in the sense that there were so many bureaucratic barriers to be knocked down— international, political and all sorts of others, not to mention technical complications," Burke says. "But the great success of balloons on Venus has made people believe that it's worth seriously investigating."

However, the enthusiasm of those who hold the purse strings at NASA has waned. Blamont was at JPL in early spring trying to revive that interest. "We really don't need NASA for this," he says, "but we think it will be important to have the Americans so they can participate with the Russian space program."

The Soviets, on the other hand, have needed little prompting. Plans for their ambitious 1994 mission include the launch to Mars of a landing vehicle, a surface rover, a relay satellite in Mars orbit—and Blamont's dual-balloon system.

The balloons would pop out of a protective capsule while descending through the Martian atmosphere. One would inflate with 70,000 cubic feet of compressed hydrogen, which would prevent it from making a new impact crater on the surface of Mars. "It wouldn't be a rough landing," says Blamont, "a collision at maybe 10 meters per second."

In the two to three weeks following its arrival on Mars, the dual balloon would be mainly a surface sampler, testing the content of the soil at different locations. Other sensors would scan just below the surface of the planet for water, relaying information to a Soviet satellite circling in Mars orbit.

A digital camera hanging from the balloons will photograph the Red Planet in greater detail than will be possible from orbit, with a much better perspective than either the lander or the rover will have.

"The camera would be able to see very tiny objects on the surface—centimeters across—from the lowest altitudes," Blamont says. "Of course, it will only see that part of the Martian surface that's immediately beneath the balloon, so it will make a kind of strip chart map as it is blown along by the wind. One of the important aspects of the mission is to be sure and track the system accurately so that this very detailed little strip chart map can be correlated with the larger area maps from orbiters."

The camera will never touch the ground. Rather, it will be suspended below the double balloons and above the guide rope that will serve as the vehicle's anchor. "When the guide rope hits the ground, its mass is removed from the balloons and the buoyancy of the system increases," Blamont explains. "Therefore, at some time there will be part of the rope on the ground and the balloons will still be in the air."

When heated by the Sun, the twin balloons will have enough buoyancy to lift the guide rope off the surface and climb about a mile above the Martian surface, drifting in the Martian winds up to 300 miles each day. Then, during the cool of night, the balloons would shrivel and drift down, planting the guide rope on the surface again.

Blamont often has said "It is difficult to walk on Mars, but it is easy to fly."

"It's a very attractive concept because it's technically simple," Burke says. "It doesn't include elaborate controls or need any commands. The balloons go up and down on their own."

Aside from adding romance to a field normally dominated by high-tech propulsion systems, planetary ballooning offers significant advantages over other methods being considered for exploring the Martian surface. According to Blamont, hopping over the rugged terrain is much safer than driving.

"There are a lot of boulders, canyons and cliffs," he says, and avoiding these hazards will require great caution. The automated Soviet rover that will accompany the balloons to Mars will have to contend with a long signal delay between Earth and the Red Planet. It will take about 20 minutes for TV pictures from the rover to reach controllers on Earth, and another 20 minutes for their instructions to make the return trip to Mars. By that time the vehicle could have become a heap of extraterrestrial junk, unless it picks its way along very slowly, stopping to take pictures, requesting new commands and waiting before moving on.

"With a rover, I think 60 to 120 miles is the maximum you can hope [to travel] during the entire mission," Blamont says. "But the balloon, with the concept that we have now, should move 600 miles in just a few days."

Well, excuse me! . . . Has someone gone through the crab nebula today?

Small prototype balloons have already flown over France, in an area about 100 miles south of Bordeaux, and at NASA's Dryden Flight Research Center in California. Others may be tested this fall at Dryden, if Blamont can convince NASA to get back in the project. If the tests go well, seven years from now Blamont's balloons will hop-scotch across the Martian surface.

"One very interesting possibility is to get the balloon operating in the polar regions and let the circumpolar winds drift it down across the polar cap," says JPL's Burke. Surrounding the caps are immense dune fields, he says, that "give evidence of centuries of winds blowing around the polar caps."

How long the balloon's Martian travels will last is unknown. Blamont guesses about 15 days—perhaps more, perhaps less. "The balloon, of course, is fragile," he says. "We don't know exactly what the wind will be like. Maybe we will have speeds of 20 to 30 meters per second. It's not clear that the balloon could survive that."

"It's a very attractive concept because it's technically simple...The balloons go up and down on their own."

▼ ▼ ▼

The Viking landers sent to Mars by the United States more than ten years ago found steady winds of less than four meters per second. "But you have to be careful," Blamont admonishes. "Our models indicate that after 50 meters in altitude the wind may pick up and become harder. That now is one of my main worries."

Most likely the balloons will make it past these hazards to simply fizzle out. The gas inside cannot help but leak slowly through the microscopic pores in the skin of the balloon. "Every day we will lose a certain quantity of gas and we will lose buoyancy," he says. Each day the balloons will not rise quite so high. Eventually they will not lift off at all.

To delay that time, instruments will be selectively jettisoned in much the same way that balloonists toss weight from their gondola to lighten the load. On Mars, that tactic will serve a dual purpose, reducing ballast while planting small-size experimental monitoring stations at the various landing sites.

The instruments will be jettisoned as segments cut loose from the guide rope that houses them. "This is a clever system, this guide rope," he says. "It is the key to everything." The rope anchors the balloon at night, protects the instruments from damage and serves as mother to a hatchery of monitoring stations.

In fact, Blamont refers to the instrumented segments of the guide rope as "eggs"—compact, self-sustaining packages of Earth technology that will continue their missions long after the balloons have flown away. He also is exploring another plan for laying eggs.

"We have suggested to the Soviets that they could lay eggs from orbit," Blamont says. "You could de-orbit 10 to 15 very small, permanent weather stations. They have accepted this idea and we are now negotiating with some friends in Europe to do this as a joint development for the Soviet mission."

Meanwhile, the United States has begun designing its own Mars Rover mission.

"We are currently engaged in trying to assess what the requirements are for our mission to land a rover, which would select samples of the surface and atmosphere and then return those samples to Earth," says Roger Bourke, mission analysis and operations manager for what he calls NASA's "pre-project" study. The current schedule calls for launch of the U.S. Mars rover in 1998, and return of the samples early in the 21st century.

Long before that, however, NASA will place a more modest spacecraft in Mars orbit, which might yet contribute to the French and Soviet project. Talks are underway about adapting the Mars Observer, which is slated for a 1992 launch, to serve as a communications satellite for the French balloons.

"As the orbiter came over the horizon and the balloon was in its line of sight, the transmitter onboard our spacecraft could interrogate the balloon transmitter," says Dr. William Purdy, project manager for the NASA mission. "That would get the balloon to start sending the data to our spacecraft. We'd store it, and at some later time transmit it back to Earth."

With so much interest now in Mars, U.S. involvement in a project similar to one already under development at NASA seems logical. Not surprisingly, the major proponent of involving the Mars Observer in the Franco-Soviet ballooning mission is Blamont. But, he warns, any joint project should be developed slowly and patiently.

When it comes to advancing scientific cooperation, the Solar System's premiere balloonist says, "I like what Henry Kissinger used to call small steps." □

Gregg Freiherr is a freelance writer in Silver Spring, Maryland who specializes in science and medicine. His articles have appeared in Science 86 *and* Air and Space.

A Discovery in Jazz

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sights and sounds that I'm going to hear. I'm not going about writing a theme song for NASA, but am approaching the experience as an artist would."

Schulman suggests that there will be cassettes of the work and a video. "Some space shuttle imagery, some launch shots, some landing shots, astronauts walking toward the pad. Maybe Jane even standing in the middle of the Mojave Desert playing her saxophone. You know the kinds of videos that you see that are very abstract and creative and symbolic—something like that," he says. The piece may even be premiered, through private arrangement and funding, at a "NASA Night: Return to Flight" at Washington's Kennedy Center or in New York.

In any case, what we will not get is a score on paper that yellows in a government file cabinet somewhere. Whatever music evolves, Bloom will be there performing it. "Could my sound be duplicated? Probably the written portion," she nods her head, then says with a puckish laugh, "but the magic? No. There's something kind of unique in it, I guess. And so it has to be me." □

C.J. Houtchens is a Washington, D.C. writer whose beat is the offbeat.

326 Days in Space

(continued from page 35)

kosmos, the Soviet-led international space consortium.

July 24 *(Day 168)* The spacefarers welcome the Soyuz TM-3 crew of Alexander Vitorenko, Alexander Alexandrov, and Syrian "guest cosmonaut" Muhammad Faris. As part of the ceremonies, each crew member reads the obligatory political telegram; Romanenko's message to Mikhail Gorbachev assures the General Secretary that they will "justify the confidence vested in us with honor," and will successfully complete the long-duration flight.

Except for Laveikin, of course. Soviet officialdom finally announces that doctors have "some reservations" about his health, and that the flight engineer will be replaced by Alexandrov.

July 30 *(Day 174)* After an emotional parting with Laveikin, who returns to Earth in the same Soyuz TM-2 vehicle in which he arrived (which has remained docked to Mir), Romanenko backs the fresh TM-3 craft away from the Kvant module. The Mir complex itself is commanded to pivot 180 degrees, and Romanenko re-docks with the station's front hatch to establish a more maneuverable configuration.

August 10 *(Day 187)* Romanenko and Alexandrov use the "Roentgen" x-ray telescope aboard Kvant to record emissions from the recently discovered supernova in the Large Magellanic Cloud, a satellite galaxy of our own Milky Way. Less glamorous duties are also on the agenda, as the cosmonauts finish unloading provisions from the unmanned Progress-31 cargo ship, which has been docked with Mir since August 6.

August 31 *(Day 206)* The cosmonauts practice procedures developed for an emergency evacuation of the space station. The drill requires Romanenko and Alexandrov to hastily navigate the narrow confines of Mir's various compartments, don their spacesuits aboard the attached Soyuz, and complete an abbreviated checklist for undocking.

October 1 *(Day 237)* Romanenko surpasses the record for continuous days in space established by cosmonauts Leonid Kizim, Oleg Atkov and Vladimir Solovyov aboard an earlier space station, Salyut 7, in 1984. Celebrations at the Flight Control Center are relatively low-key: there are still months left in Romanenko's mission, and other records left to break.

October 3 *(Day 239)* On the eve of the 30th anniversary of the launch of Sputnik 1, Romanenko speaks by radio to the audience at a commemorative concert in Moscow. He jokes with master of ceremonies and fellow cosmonaut Georgi Grechko that, after nearly eight months in orbit, he wouldn't mind being in the hall with Grechko right at that moment.

SOVFOTO/TASS

October 10 *(Day 246)* Romanenko and Alexandrov enjoy a Saturday off, although they still perform routine maintenance of Mir's systems and conduct visual observations of the Earth. With "warm words and congratulations," Romanenko marks the birthday of his wife, Alevtina.

October 16 *(Day 252)* Both crewmen undergo the usual medical tests; Romanenko's pulse rate remains fairly constant, at 65 beats per minute. But there is also a sign that the long duration of the flight is taking its toll on his efficiency. TASS reports that the cosmonauts will have the next two days off.

October 22 *(Day 258)* Romanenko passes fellow cosmonaut Valeri Ryumin to become the world's most experienced space traveler. Counting the duration of his two earlier flights, Romanenko has now spent a total of nearly one year in orbit.

November 10 *(Day 277)* Romanenko starts his tenth month in space monitoring an experiment designed to reduce fuel consumption during orbital maneuvers. The Progress-32 transport craft undocks from Mir, conducts a practice approach and rendezvous, and re-docks with the station on the next orbit, 90 minutes later.

November 24 *(Day 291)* Earth observations dominate the crew plan for Romanenko and Alexandrov. They photograph selected targets on the ground and conduct experiments to test the opacity of the atmosphere from space.

December 3 *(Day 300)* Soviet officials and cosmonauts send congratulatory messages to Romanenko as he passes the 300-day mark aboard Mir. But the Soviets also admit that Romanenko is "visibly tired" and has suffered a 15 percent decrease in leg muscle volume as measured by onboard equipment—a continuing problem for long-term space travelers whose muscles no longer have to fight gravity.

December 15 *(Day 312)* The Flight Control Center has reduced the work day for Romanenko and Alexandrov to four and a half hours, and the cosmonauts are sleeping nine hours each night. The crewmen use their time efficiently, however: they transfer fuel and oxidizer from Progress-33 to Mir's propellant tanks, maneuver the entire station complex in a series of attitude control experiments, and aim the Glasar ultraviolet telescope at the constellation Lepus.

December 23 *(Day 320)* Cosmonauts Vladimir Titov and Musa Manarov are flown to Mir by test pilot Anatoli Levchenko. Romanenko and Alexandrov eagerly acquaint their relief crew with the station's idiosyncracies, and begin to pack for the return flight home.

December 29 *(Day 326)* "I feel great, and so does the crew!" Yuri Romanenko feels the snow-covered soil of Kazakhstan beneath his feet for the first time in nearly eleven months after climbing from the Soyuz TM-3 spacecraft, which has parachuted to a landing on solid ground. He apparently is in excellent shape, and is even able to stand up briefly on the plane ride back to the Baikonur spaceport.

Romanenko jokes that he had to pull Alexandrov away from the experiments during the last day of their marathon mission: "You get attached to space," says the world record holder for time in orbit. "On a long flight, you just feel like going on and on..."

Les Dorr is a freelance writer in Germantown, Maryland who writes frequently on the Soviet space program. His article on Vladimir Dzhanibekov appeared in the April issue. □

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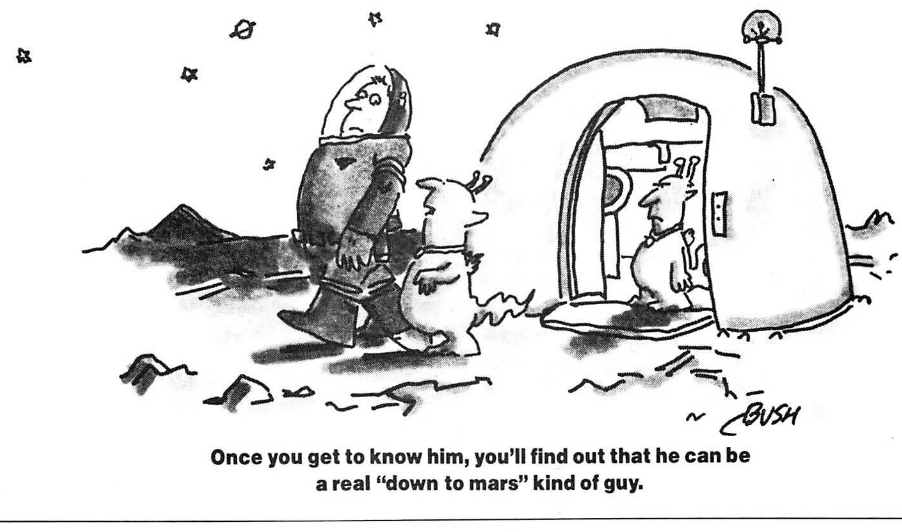

Once you get to know him, you'll find out that he can be a real "down to mars" kind of guy.

DESTINATIONS

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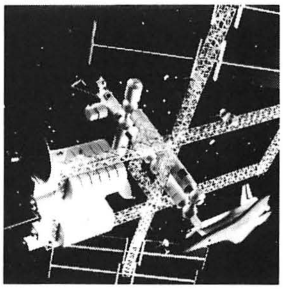
who build
beneath the stars.*

*Edward Young
From Night Thoughts
1742-1746*



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